



cinefex

number 88
\$9.50
Canada \$14.00

cinefex

... the journal of cinematic illusions

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PRINTED IN USA

CINEFEX 88 – January 2002. Published quarterly at P.O. Box 20027, Riverside, CA 92516 – Tel: 909-781-1917. Printed by Valley Printers, Riverside, CA. Contents copyright © 2001 by Don Shay. All rights reserved. Reproduction in whole or in part, in print or on the Internet, without written permission is prohibited.

Sleight of Hand 68

Having singlehandedly captured the fancy of an entire generation of adolescent readers and ignited a pop culture phenomenon, English author J.K. Rowling's *Harry Potter* novels – about a novice wizard and his magical adventures at a school for the supernaturally gifted – were ripe for translation to the big screen. With *Harry Potter and the Sorcerer's Stone*, Warner Brothers has taken up the gauntlet, presenting the first installment in a highly anticipated movie series based on the Rowling books. Director Chris Columbus, determined to remain faithful to the source material and its legion of fans, based the production in England and assembled an all-English cast along with a virtual army of world-class artisans and technicians tasked with producing their own brand of alchemy in the service of the show. Joining forces with special effects supervisor John Richardson and makeup effects artist Nick Dudman was Oscar-winning visual effects supervisor Robert Legato, who orchestrated the efforts of eight visual effects facilities on both sides of the ocean, creating everything from wondrous settings to magical creatures to a thrilling aerial tournament played on broomsticks. *Article by Joe Fordham.*

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MONSTERS IN THE CLOSET

ARTICLE BY JODY DUNCAN



As a child, there were two things Pete Docter knew with absolute certainty: the toys in his room came to life when he was not present, and there were monsters hiding in his closet, waiting to scare him at night. Pixar Animation Studios explored the first notion with humor and insight in *Toy Story* and *Toy Story 2*; and now, with *Monsters, Inc.*, the renowned computer animation studio— as part of its five-picture deal with Walt Disney Pictures— has taken an equally delightful look at the second. The tale revolves around James P. Sullivan, a professional monster-in-the-closet who first fears— then grows to love— a little girl named Boo who ‘invades’ his monster world.

Monsters, Inc. marked the directing debut for Docter, who had worked as supervising animator on *Toy Story*, the first-ever full-length 3D animated feature, directed by Pixar vice president of creative development John Lasseter. “After *Toy Story* was done,” Docter recalled, “John, who was starting in on *A Bug’s Life*, gave me the opportunity to go off and think about what to do next. So I began playing with the idea of monsters in the closet. And as I thought about that I realized that, of course, the reason monsters do that is because it’s their job. They clock in, they clock out, they work at this big factory scaring kids, harnessing their screams as a means of powering their lights, their cars, everything. But, like



For its fourth CG feature, *Monsters, Inc.*, Pixar Animation Studios created a comic world in which monsters power their technology by harnessing the screams of human children. Slithery Randall Boggs aspires to wrest the title of *Monsters, Inc.*’s top scarer from hairy giant James P. Sullivan and his bulbous assistant Mike Wazowski.



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people who work in a nuclear reactor plant, the power source itself is so powerful, the monsters believe it to be toxic. And so it is only the trained, elite monsters that go in and scare kids—because none of the others want to go anywhere near them.” Central to the premise was the notion of many different ‘scarer’ companies working from industrial complexes in the monster-world city of Monstropolis. “Monsters, Inc. has the patent on the ‘Through the Closet Door’ method of scaring; but there are others— which we don’t actually mention in the film— like Fearco, which does ‘Under the Bed’ scares, and Scaremasters, which has the ‘Bump in the Night’ franchise. But Monsters, Inc.’s bread and butter is the ‘Through the Closet Door’ scare, and they are the number one factory.”

Five years elapsed between Docter’s initial notion and the release of Monsters, Inc., the first year and a half spent just developing the concept— a process that involved Docter and his creative team sitting in a room, brainstorming, then pinning up cards on which story ideas were written until a narrative structure began to emerge. The creative team also drew up on-the-fly sketches and cartoon gags, doodled on giant rolls of butcher block paper, the best of which were cut out and added to the wall of story ideas.

As Pixar’s leading creative force, John Lasseter was involved at this and every other stage of the film’s development. One of Lasseter’s contributions was the idea that the monsters would be afraid of the children they were scaring, with even a youngster’s sock considered deadly. To illustrate the point, the creative team devised a scene in which a monster returns to the factory from his scaring shift, a child’s sock inadvertently stuck to his back. Sirens wail and lights flash as the CDA— ‘Child Detection Agency’— swoops in wearing haz-mat suits to destroy the sock and ‘disinfect’ the hapless monster. “It was a great idea,” Docter said. “The reversal of the monsters being afraid of the kids really helps the audience get on board with the story.”

The impromptu sketches and drawings produced in the story room eventually led to a color strip made up of postage-stamp-sized pastels— rendered by Dominique Louis of the art department— for every scene in the film. “The color strip was an early attempt to define a color palette to support the story,” stated Bob Peterson, who headed up the story department, “its moods and its monster world. The art department could glance at the drawings and see where we had too many monochromatic scenes, or scenes that felt too cold or too rich or too angry.” With basic story decisions made, Peterson oversaw the storyboarding of specific sequences. Those boards were then shot on video and edited on an Avid, providing a 2D rough cut of the film, from beginning to end, complete with a temporary voice-track recording of Pixar personnel performing lines of dialogue.

But neither the storyboards nor the dialogue was set in stone— both were subject to revision as the movie continued to evolve. “The story department gave the art department updates every step of the way,” said Peterson. “Then the art department might say, ‘Why don’t you try this?’ So we’d throw that new thing into the reels to see if it worked. There was a lot of back and forth— not just with the art department, but with animation, as well. The animators are very smart and funny people, and they were always coming up with ideas. We’d look at them, and say, ‘Okay, let’s retool the story so we can use this great thing someone has cooked up.’”

“By the time we were through,” stated Docter, “we had probably created the equivalent of four or five feature films. The film was constantly changing and evolving. We’d have our first three sequences all figured out and be working on the fourth when something we discovered in doing the fourth would make us go back and change the first. To us at Pixar, the story is key. We work and rework and rework it until it is right.” Despite their work-in-progress nature, the 2D reels gave everyone a sense of the pacing and emotional impact of the final film. “It’s like music. You can talk all you want about Mozart’s music and explain that it’s ethereal and rich; but it’s only when you hear the music that you really get it. Even in storyboard form, looking at the film gave everyone a sense of the pacing. We could feel whether or not it had any heart to it, or if it had characters you could care about.”

All of the story and art concepts gelled into a screenplay written by Pixar director and unofficial in-house writer Andrew Stanton and Dan Gerson. That final storyline included not only fifty-plus supporting and background monster characters, but also lead monsters James P. Sullivan (voiced by John Goodman)– a horned, furry monster who is a top ‘scarer’– and his assistant and best friend Mike Wazowski, a green, spherical, one-eyed monster (Billy Crystal). One of many considerations in the monster design effort– overseen by production designer Bob Pauley, while production designer Harley Jessup focused on environments– was finding a balance between ‘scary’ and ‘appealing.’ “We were making a Pixar film,” Pauley explained, “so this was not going to be a world where the monsters were scary and horrible. It was a diverse world where you’d see everything from little monsters to giant monsters– and they’re just like us. We didn’t want grotesque, creepy monsters.”

“They definitely had to have appeal,” Docter agreed, “but we also had to keep in mind that they were monsters. They couldn’t just look like fuzzy animals. So, in the case of Mike, for example, we gave him sharp teeth, but connected them so they wouldn’t be as hard-edged. It was all a matter of keeping the shapes slightly rounded, and not as sharp and angular as they could have been.”

Sculptor Jerome Ranft translated lead monster designs from drawings to clay maquettes and gray-painted, full-size heads, marked with a grid and digitized for the purposes of computer modeling and animation. “Jerome is an awesome character sculptor,” stated Pauley, “and he understood the needs of the 3D computer modeler. When he was sculpting a head that was going to be digitized, he knew that sculpting the mouth partly open would be helpful, for example.” A guiding principle in the design of the monsters was that their anatomy, though fantastic, be grounded in some kind of reality. “If their structure and form were based in reality, we could push textures or paint to make the character more playful. These were mythical characters, and although they didn’t have to be ‘real,’ they had to be believable.”

Sullivan was among the most difficult characters to design, largely because his character, like the story, kept changing. “We were trying to design a character without actually knowing who he was yet,” Docter noted. “In the first draft of the story, Sullivan was a scarer, but not a very good one. He was sort of a fumbling scarer, and a bit of a boob, who was trying to work his way up in the company. In a middle stage, he wasn’t a scarer at all, but a janitor, watching the scarers from afar, longing to be in their place. We were trying to find icons for those types of characters, so the audience would get an immediate read on him as soon as they saw him. The janitor version, for example, might be a scrawny guy who is afraid to get out in the world; and that would be a much different-looking monster than the top-scarer Sullivan.”

Through all his iterations, however, Sullivan had fur; and so Pixar’s tools department initiated fur research and development at the earliest stages of production. Cloth simulations also had to be explored, as Docter had decided to put the little girl Boo in an oversized, loose-fitting T-shirt for much of the film. “I felt that would be really appealing,” Docter observed. “But the clothing we’d done on feature films up to that point was limited to tight-fitting, spandex-type things– which are easier because they don’t fold and wrinkle and drape. So we had to totally reinvent the software that simulates cloth, as well as deal with the fur. My mandate was that I didn’t want the animators to have to worry about fur or cloth at all. I didn’t ever want to send something back to animation because the simulator couldn’t handle it.”

The fur simulation, in particular, not only had to perform quickly and flawlessly, it had to create fur that was both credible and appealing. The importance of appeal had been brought home to supervising technical director Tom Porter after his work on Toy Story. “I led the shading effort on Toy Story,” Porter recalled. “Six months before the film came out, I brought in a good friend to look at some of the images on a monitor. I was intensely proud of the work, but my friend was unimpressed. He had three young girls at the time, and he told me: ‘My girls’ favorite movie is The Lion King– they loved how cuddly it was. This computer graphics stuff of yours just doesn’t look as cuddly.’

You come off a large body of work like that, you’re really proud– and a trusted friend cuts to the essence of it saying, ‘It’s not cuddly’. That stuck in my craw for years. Monsters, Inc. was an opportunity, with all the hair and clothing, to create a much softer, approachable, cuddly look.”



Story supervisor Bob Peterson, co-director David Silverman and director Pete Docter examine storyboards for the film.



Sequence supervisor Steve May and simulation and effects supervisor Michael Fong review a nearly completed shot.

The technical crew started the development of the fur simulation by studying reference, such as samples of llama hair. “The art department gave us a big poster board covered with llama fur,” said simulation and effects sequence supervisor Steve May, “so, somewhere, there was a cold llama. They told us: ‘Try to get this fur look. This is the kind of fur we’re going with for Sullivan.’ We also looked at faux fur; and for the fur on Sullivan’s face, which is very short, we studied a bear head. We had the usual assortment of reference photos of all kinds of animals, but we found the llama fur was the best reference.” The technical department also studied movies such as the *Mighty Joe Young* remake, for which Dream Quest Images and ILM had created remarkably convincing gorilla fur for the CG version of Joe. “That was very helpful, because Sulley was closer to a gorilla than any other animal. What we got out of *Mighty Joe Young*, mainly, was the realization that it was actually possible to make realistic-looking fur. We couldn’t tell which parts used the guy in a suit and which parts were computer generated—which was a credit to those guys.”

But whereas *Mighty Joe Young* had been able to rely on the man-in-a-suit approach for some shots, every shot of Sullivan—which eventually totaled 800—would be computer generated. With so many shots to deliver, an ultra-efficient fur system had to be developed. “Because he was going to be in so many shots,” said May, “our goal with Sullivan was to establish a pretty solid look up front so that we could avoid doing much grooming or tweaking per shot. David Baraff and Andy Witkin in the tools department developed a simulator that pretty much never broke. So we could stick Sullivan in all kinds of awkward situations, and the animators could do what they were doing with other characters that didn’t have fur—and the fur would always do the right thing.”

With so many shots involved, Pixar created an entirely new department—called ‘shots’—to deal with simulation and effects. “Shots took care of anything that didn’t fall into our normal pipeline,” said Galyn Susman, who headed the department. “That pipeline had included layout, set dressing, animation and lighting—but that leaves a bunch of other stuff. Where do you put effects? Where do you put rendering? Where do you put simulation? The shots department took responsibility for all of these areas. It was great to have a department where you could lump all of these really interesting challenges together. It gave us a lot of fluidity, with a nice composition of people.”

Typically, animators would hand over their animated, but furless Sullivan to the shots department, where guide hairs would be simulated, determining fur length within specific areas of Sullivan’s form—longer hairs simulated in some areas and shorter hairs simulated in others, such as the face. “We developed this thing called a ‘builder,’” said Steve May, “which is similar to a shader in the RenderMan shading language. A shader is a program that says: ‘Here’s how you shade a point on a surface. Here’s how you make it look like it is made of metal or wood or marble.’



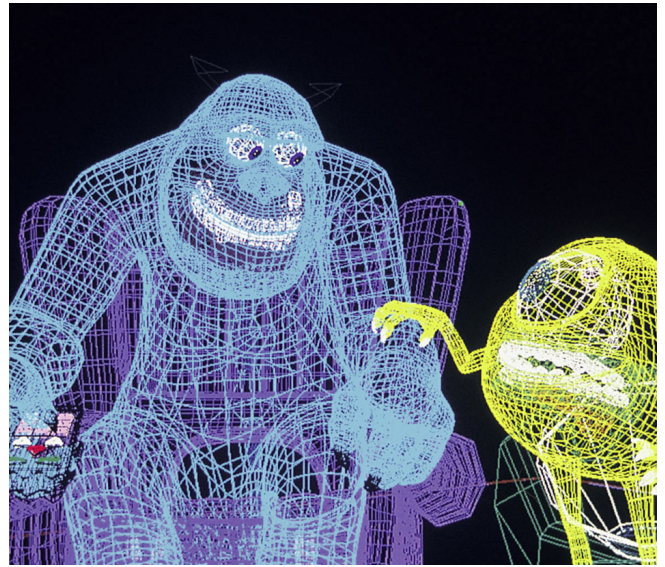
We took that a step further for the hair, building actual geometry to grow hair when the image was rendered- and not until then. We'd regrow the hair every time we rendered Sullivan."

Sullivan's builder was modified for other furry monsters in the film, such as Yeti, an abominable snowman character with a coarser, more curly coat of fur. For all the characters, the digital artists would minimize, as much as possible, the number of hairs to be rendered. "The hair software was fairly intelligent about the camera. It would know, for example, when the hairs on Yeti's back were not going to be seen from a front-on camera view; so if we were to turn that character around in that shot, we'd see that he was naked in the back. To save rendering time, we wouldn't grow those hairs that weren't going to be seen."

To expedite the actual 'styling' or movement of the hair, simulation and effects supervisor Michael Fong wrote a tool that essentially performed virtual hair brushing. "We'd load Sullivan up," explained May, "then use this tool, which was like Photoshop in that it had different sizes of brushes. With our mouse, we could move a cursor across Sullivan and this would direct the flow of his fur. That worked very effectively for furry monsters, where you had a lot of hair that you wanted to sculpt quickly." Clumping was an important characteristic of the monsters' fur coats. "Some of our first tests didn't have clumping, so they looked like a Vidal Sassoon commercial, with beautiful, straight hair swimming in the wind. That's not really what a monster looks like. Pete pictured them more like dragging around in the dirt, their fur all greasy and nasty, and clumping is what brought that kind of realism to our test. When we started doing clumping, we knew we were heading in the right direction."

Other controls determined hair/fur coloring- in Sullivan's case, a blue and purple-spotted coat. The basic color scheme would be painted on a character's skin, and the hairs growing out of any given area would take on the root color painted there. "A hair that grew out of a purple spot, for example," related Michael Fong, "would also be purple. But it was procedurally modified so that the purple was not the same color from the root to the tip of the hair. It would be slightly faded

The scariest thing about being a scarer is the fear of physical contact with a child, considered by the monsters to be toxic.



A formidable challenge was developing fur that was both credible and cuddly. Simulation tools were created that allowed animators to articulate Sulley without having to concern themselves too much with how his hair was going to behave.



towards the ends, as if the tips had been bleached by the sun.”

“One of the cool things that happened with this approach to the color,” added May, “was that it created nice organic patterns once the fur was

there. We could paint relatively simple geometric shapes on the skin; but then, because the hairs were irregular and had all this ‘scraggle,’ as the hair grew out of those simple shapes, they got much more organic, random and natural looking. It was a nice by-product of doing it this way.”

A self-shadowing technique also contributed to the depth and rich quality of the hair. “Other studios had shown that it was possible to make fur on characters using RenderMan,” said May, “but the tools group had to do a lot of work to make it possible to do 800 shots of a big guy with really long fur. They had to make the rendering of hairs faster, and a big part of that was making them self-shadowing. Tom Lokovic developed something we called a ‘deep shadow map,’ which allowed us to do self-shadowing on things like fur, and also smoke and other kinds of fuzzy objects.”

The fur was given its final sheen through extensive backlighting, which accentuated the silhouette around the furry creatures. The show’s overall lighting style—characterized by a bright, colorful palette preferred by Docter—was first worked out in the color strip created early in production. Art directors Tia Kratter and Dominique Louis worked closely with supervising lighting lead Jean-Claude Kalache and directing lighting artist Janet Lucroy, who interpreted the lighting scheme specifically for Sullivan’s fur. “Sullivan required an entirely different approach than the characters from previous Pixar films,” Kalache said. “Backlighting was far more crucial. Janet worked with Ben Jordan of the shading staff to incorporate some clever fake fur shadowing for the fill and bounce lights, to give a natural look to the fur.” The art directors worked also with shading supervisor Rick Sayre who, with his team, created thousands of shaders to give the monster world a stylized and textured look.

A tandem effort to the fur development was the creation of a cloth simulation, used primarily for Boo’s oversize T-shirt. “Two or three years ago,” commented Tom Porter, “we were very concerned about the problems that could arise from having a child running around in half the film wearing a big T-shirt. We were also concerned about what would happen when she raised her arms or bent over, with the T-shirt scrunching up. But Mark Henne worked with the tools group to completely annihilate those problems! Boo could be walking, moving her arms— it didn’t matter. In the last three months of production, nobody worried about cloth at all. It performed so well, so consistently, that we all just sat around in amazement. It was terrific work by these guys. The only thing they asked, initially, was that Sullivan never pick up Boo by her clothing. And, of course, the story department came up with a storyboard of Sullivan picking her up by the back of her T-shirt. ‘Keep working, boys!’”

While the technical team wrestled with issues of fur and cloth, a team of computer modelers, led by Eben Ostby, built models for all the characters, using Pixar’s proprietary Marionette software. As reference, the modeling team studied a number of real animals, their anatomies

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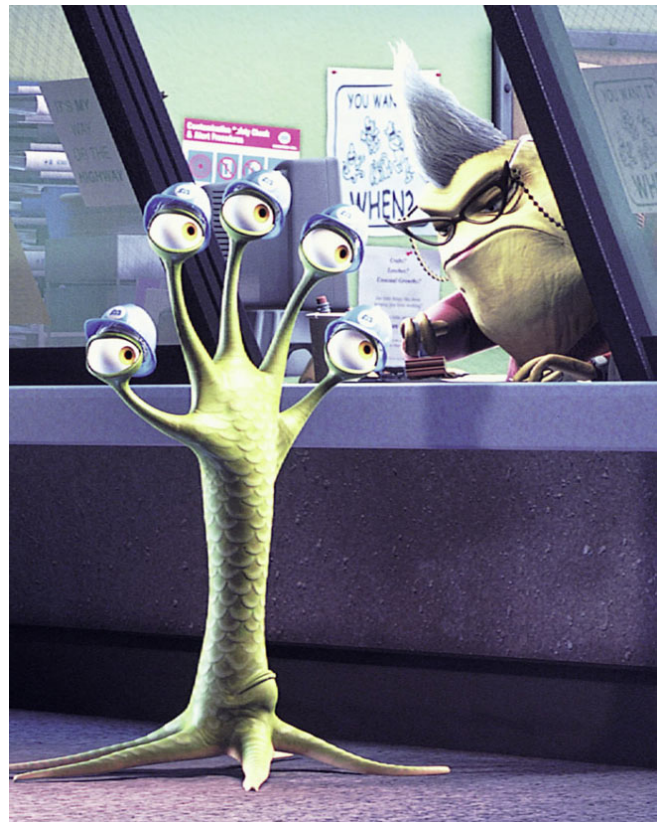
and their skeletal structures. Sullivan's form required more tweaking than any of the others, partly because of his furry nature. Once fur had been applied to his initial structure, he looked like a giant puff-ball. "We had to think: 'Okay, here's how we want him to look,'" related Docter, "'so let's shave him and now let's build in the computer this kind of scrawny version of him, then put hair back on him. That took a lot of back and forth before we were happy with how he looked."

The main modeling challenge, however, was just building the wide range of characters, since a single underlying structure could not suffice for all the different monster shapes and sizes populating Monstropolis. Pixar had delivered huge crowds of ants for *A Bug's Life*; but in that case, the filmmakers had been dealing with creatures who were more or less identical, structurally- which meant that entire crowds could be cloned from the same basic model. In contrast, the characters in *Monsters, Inc.* varied widely. "I kept trying to focus Pete back to a few species of monsters," Tom Porter recalled, "but he always wanted to break out of that- 'No, no, the gag here involves a monster with twenty-two arms!'" Character technical director Rob Jensen ultimately devised software called 'Mkmonster,' a monster-making kit that allowed for the relatively fast and painless modeling of 150 vastly different character designs.

Once all the characters had been modeled, the animation effort, overseen by supervising animators Glenn McQueen and Rich Quade, went into full swing. As always, the characters' animations, behaviors, personalities and quirks were cued off the vocal performances, which had been recorded only after the entire film had been committed to storyboards and everyone had developed a sure sense of who the characters were. "Sullivan was probably the hardest guy to cast," Docter recalled, "just because his character went through so many stages. When the story finally landed with him being the top guy, John Goodman was a great choice because he has such a power. Sulley was always a big, tough guy in my mind, but with a soft, sensitive side to him; so John Goodman worked out great." Docter and other key Pixar personnel traveled to record the artists in studios close to their homes or wherever they were currently working. Most of the recording was done in Los Angeles and New York, with a typical session lasting four hours. "We had fourteen or fifteen sessions with John Goodman and Billy Crystal, in some cases together- which is unique. Usually we just do one person at a time. For *Toy Story*, Tom Hanks and Tim Allen were at opposite ends of the country, recorded two years apart- and you put them together and it looks like they're arguing. In this case, though, we had the two of them together in some cases, which created a very natural chemistry. They would start to banter and make stuff up and play around- it was great. They came up with a lot of things that helped define the characters."



More than fifty monsters were created for the film, each carefully designed to strike a delicate balance between being scary and appealing.



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The character of Boo was voiced by a complete unknown- Mary Gibbs, the toddler-aged daughter of Pixar story artist Rob Gibbs. “Mary was around two-and-a-half or three at the time,” commented Docter, “and she came in to do temporary voice tracks to put up on the reels, along with temporary music and so on, just to give us something. We’d just done the Boo voice ourselves at first; but we found that it really took you out of the film to have an adult doing a kid’s voice. So we brought her in. She couldn’t quite talk yet, but everyone fell in love with her voice.” So much so, in fact, that the little girl became the voice of Boo for the final film, as well. Capturing a lead performance from such a young child, however, required patience and persistence. “At first we tried just having her stand in front of a mike; and I would say, ‘Act really scared,’ or ‘Pretend like you’re this or that.’ And she was like, ‘Nyuhh,’ not really into it. So what we ended up doing was giving her a lot of sugar and following her around with a boom mike, recording whatever she did naturally. I brought in puppets, and she would talk to the puppets. There was one point where she was upset at her mother because she couldn’t have another candy bar, and she started to have a fit: ‘Uhhhhh!!!!’ We used that in a scene in Mike and Sulley’s apartment, where Boo wants a teddy bear. The sound editors did a terrific job of taking little snippets and putting them together to create this performance.”

Inspired and guided by the vocal performances, Pixar’s team of animators worked for two full years to create the animation for the feature-length film. The most difficult character to animate was ‘number two’ scarer Randall Boggs (Steve Buscemi), a fleshy lizard with eight dexterous limbs, who could walk upright on his hind legs, but could also drop low to slither around in reptilian fashion. “It was a lot more work than animating two legs,” Docter commented. “Animating something that is bipedal is fairly well understood, technically and artistically, because we’ve done it so many times before. But a lot of Randall’s movements were spooky and snake-like- he would zip around things to scare kids.” Subtle facial animation was another major challenge, particularly for the character of Mike, who was essentially a giant eye and a mouth- and nothing more. “Andrew Gordon, the lead animator on Mike, did a great job of making that work. We found, even early on in storyboards, that we could get everything we wanted, pretty much, out of the one eye. If he had to look confused or a little skeptical, then we’d just bring up one side or the other using the one brow- just as you normally would use two- and that would suggest the general feel of it. But there were things more challenging- such as a scene where he sniffs his arm, and says: ‘Peew! Can I borrow your deodorant?’ He has



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no nose, and he has no head, so he can't really turn and sniff; but Andrew did little cheats, bringing the arm forward and wrinkling Mike's lip."

All of the characters were put into computer generated sets, the design and execution of which were overseen by Harley Jessup. Environments included Boo's bedroom, the industrial factory that houses Monsters, Inc., and the factory town of Monstropolis. Pixar principals toured a number of locations to gather reference for the movie's various settings, including Pittsburgh, where they soaked up the ambience of an industrial city. "For the factory," explained Bob Pauley, "we went to a blimp hanger at Moffett Field, about an hour south of our facility. It is huge- you could fit two Titanics side by side in there. We needed to see what an enormous structure would look like from the inside and the outside." The crew also visited a local gas refinery, looking for inspiration.

Ultimately, the fright factory was designed as a poured-concrete, sixties-style edifice. Outlying buildings featured strong girders and steel bases to support the giant, heavyset monster workers, while the main factory building had a tooth motif. "The overall design philosophy for Monstropolis was to think of it as our world- only monsters live there," said Docter. "So things that would be wood or plastic in our world would be steel or stone in this one, since some of these guys weighed 15,000 pounds. Also, where we might have flowers and curlicues as the decorative trim on doors or whatever, the monster world would have teeth or eyes - things that monsters would find aesthetically appealing." Another consideration was the variety in the monster characters. While our world serves relatively same-sized human beings- with most adults in the five- to six-foot range- the monster world was home to a wildly diverse monster population. "Some of the monsters are a foot and a half tall; others- like Sullivan- are eight feet tall. But they all have to be able to reach a doorknob and walk through a door. How do you do that? We used multiple doorknobs on the doors. We also designed flexible headsets for phones, so characters with their mouths way down here and their ears way up there could still talk on the same receiver." Though dressed up with these flourishes, monster-world props still had to look familiar enough to prevent audience confusion. "There was a natural inclination to think in terms that were too fantastic: 'Wow, this is a monster world- I can do anything!' But that led to designs that were so fantastic, we couldn't tell what they were. 'Is that a copy machine or a table?' 'It's a telephone.' 'Oh. It doesn't read as a phone.' So we'd start with the real thing- like a phone- and then add monster-world details."

One of the film's most elaborate digital sets is the enormous door vault in Monsters, Inc., which stores the closet door of every child in the world. Each door hangs at a different level and is accessed via a conveyor belt system. The door vault posed a major challenge to the Pixar digital set construction crew. "Any time you have a huge, filled space like that," observed Tom Porter, "it's a modeling challenge because you're worried about the overall scene complexity, and whether you can even describe it to RenderMan and get it rendered



in a reasonable amount of time. This vault had, theoretically, thirty-five million different doors—and how do you provide the complete detail of all that geometric complexity?” Tim Milliron masterminded a render time-saving solution that allowed for the modeling of low-resolution doors at a distance, transformed into high-resolution versions once a particular door had come around the conveyor belt track to front of camera.

With the release of *Monsters, Inc.* on November 2, a beleaguered American public welcomed the charming, funny and heartfelt offering of computer animated escapism, the fourth in a series of feature films created by Pixar in the last decade. The studio has not only moved and expanded its physical facility in that period, it has also evolved from a relatively small group of artists and technicians performing every task required to complete a computer animated project— story, art, editorial, animation, layout, set dressing, modeling, shading, lighting, shots and rendering— to a powerhouse, high-profile force in the film industry, with a staff of nearly six hundred. But throughout its growth, Pixar Animation Studios has remained true to its founding philosophy, simply stated on its web- site home page:

Though Pixar is the pioneer of computer animation, the essence of our business is to create compelling stories and memorable characters. It is chiseled in stone at our studios that no amount of technology can turn a bad story into a good one.

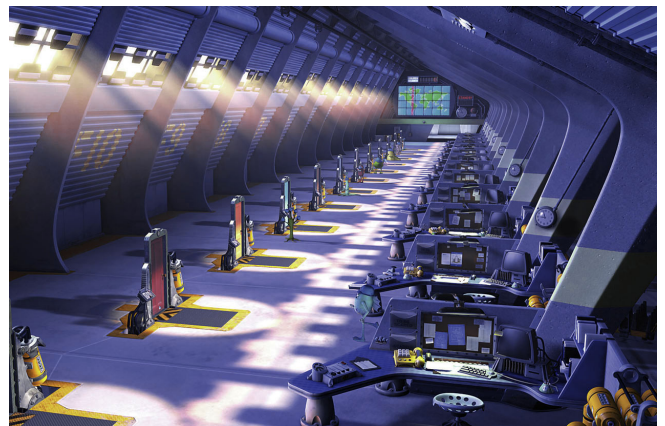
Among those responsible for formulating that philosophy was John Lasseter, whose creative impulses have infused every one of Pixar’s shorts, commercials and feature films. “John is an amazing entertainer,” Pete Docter concluded, “and I mean that in the best possible way. He isn’t interested in doing an ‘art’ thing just for art’s sake. He’s interested in making people laugh, making people cry, reaching people. I think we’ve done that with *Monsters, Inc.* It has real heart— and that’s the thing I’m most proud of about the film.”

Monsters, Inc. photographs copyright © 2001 by Disney/Pixar. All rights reserved. Interviews for this article were conducted by Joe Fordham. Pixar photographs by Linda R. Chen. Special thanks to Karen Hartquist, Howard Green and Holly Clark.

Conspiratorial crustacean Henry J. Waternoose, the chief executive of Monsters, Inc., heaps praise upon his company’s most skillful scarer.



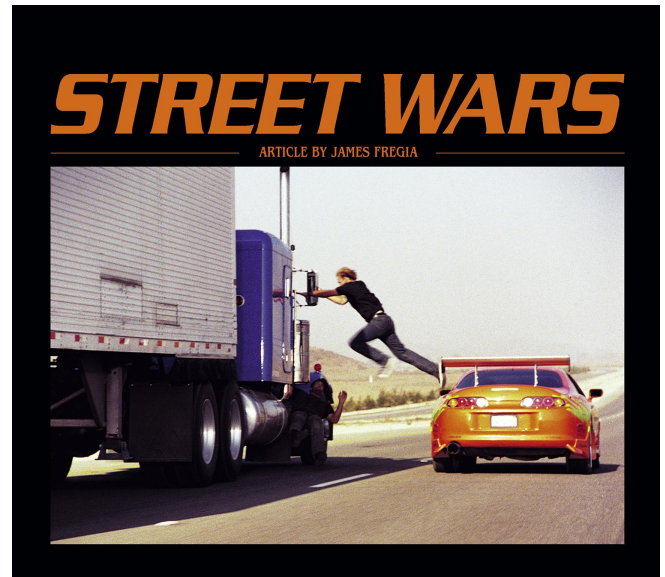
Computer generated sets, ranging from quaint city exteriors to massive industrial workspaces, embraced a wide array of visual styles.



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STREET WARS

ARTICLE BY JAMES FREGIA



Beginning with the first hot rod feature, *The Devil on Wheels* in 1947, filmmakers have looked for innovative and creative ways to capture the raw, rebellious world of drag racing down America's streets and highways. After the 1955 classic *Rebel Without a Cause*, which established James Dean's iconic image and showcased white-knuckle car races, a string of B-movies perpetuated the genre, which then faded into obscurity- until now.

The Fast and the Furious, directed by Rob Cohen, revisits that adrenaline-pumped world of street racing. The story centers on Brian O'Conner (Paul Walker), an undercover police officer who infiltrates a Los Angeles gang of illegal street racers suspected of a string of big-rig hijackings. To earn the respect of the gang, Walker must first challenge their leader, Dominic Toretto (Vin Diesel), the king of underground racing. As a strong bond develops between the two men, Brian is forced to choose between loyalty to his mission and loyalty to his new friend.

Cohen's goal was to give the racing sequences in *The Fast and the Furious* a unique stamp and a fresh look. Early discussions with second unit director and stunt coordinator Mic Rodgers made it clear that much of the desired footage could be obtained in-camera with old-fashioned stunt work and a new, innovative tow-car rig. However, Cohen knew he would have to rely on a large number of bluescreen shots and computer generated effects to create the illusion of the turbo-charged vehicles traveling at speeds up to 150 miles per hour, and to effectively place viewers squarely in the driver's seat. In addition, Cohen wanted to explore places no camera had ever been, moving deep inside the high-performance engines themselves for a glimpse of the power behind the machines.

To handle the bulk of the visual effects work- some 153 shots involving two key racing scenes- Cohen approached Bill Taylor and Syd Dutton of Illusion Arts, frequent contributors to the director's previous film and commercial endeavors. Dutton proposed that Cohen enlist the services of Illusion Arts senior matte artist Michael J. Wassel as overall visual effects supervisor on the show. Although it would be his first assignment serving in that capacity, Wassel was an obvious choice- an avid car enthusiast with an extensive background in illustration and industrial design, and a former student of the Art Center College of Design, which has produced

designers for General Motors, Ford and other major automobile manufacturers. “I’m a car guy,” Wassel admitted, “and all that specialized knowledge certainly helped.” Wassel subsequently recruited Hammerhead Productions and Digiscope to the project, and joined a team that included production designer Waldemar Kalinowski and director of photography Ericson Core. Special effects veteran Matt Sweeney- a longtime acquaintance of Mic Rodgers and a real-life Pro Rally car racer- was enlisted to oversee all of the practical effects work.

Chief among the practical considerations that Sweeney and Rodgers addressed before the start of principal photography was design and construction of a breakthrough camera car rig that would enable Cohen to shoot driving footage with the real actors behind the wheel. Rodgers had been tinkering with designs for such a rig off and on for ten years before he and Sweeney brought the idea to the attention of Cohen and executive producer Doug Claybourne, ultimately securing their go-ahead to commence construction. “We had tried for years to talk other production companies into letting us build one for chase sequences,” remarked Sweeney, “but, until now, no one was interested.”

The driving rig, designed by Rodgers and aptly dubbed the ‘Mic Rig,’ offered far more maneuverability than the standard car tow systems previously in use. “Whenever you put a car on a trailer,” stated Sweeney, “you can only safely go thirty or forty miles per hour in a straight line. You can’t maneuver, and the car is always positioned too high. With this rig, we could go in excess of eighty miles per hour, and get some really exciting stuff.” Constructed over a period of three weeks, the rig began as a standard, full-size van, which Sweeney and his crew adapted by cutting the back of it off and exposing the frame. They then extended the back of the van by six feet and mounted a specially rigged picture car on the platform. Though the prop vehicle was stripped of chassis, wheels, drive train and engine, the car’s interior remained fully intact, with seats, five-point seatbelts and interior décor by the production art department crafted to match real racecar interiors. The frame was placed on rails, along with a generator at the rear of the setup, while a camera crew positioned itself at the front of the van. In this way, the actor could sit in the Mic Rig prop car while a stunt driver in the van did the real driving- power slides, spinouts and other maneuvers that could never have been done safely on a standard process trailer. “The rig worked better than we had hoped. There was no height disparity like we normally get when we’re using a camera car, since the picture car was at the exact same height that it would be on the street. We got all the exciting action in the background behind the actor, and things like the lean of the actor as he was going through centrifugal force. When we tow a car the traditional way, the actor can’t really turn the steering wheel, but here he could spin it like crazy. All the fancy maneuvering and jumps that were in the movie were done using the Mic Rig.”

While such practical preparations as the Mic Rig were underway, Wassel and his team at Illusion Arts were also in the midst of preparing for the race scenes. The visual effects team’s major focus was an early sequence in which Brian’s driving skills are put to the test as he squares off against Dominic and two others during a late-night, high-



stakes road race on a desolate Los Angeles street.

Dubbed the 'Das Boot' sequence- because of a shot that echoed one in the 1981 World War II submarine film where bolts pop out under pressure- it was a key scene that would set the tone and style for the rest of the picture. For that

initial drag race, Cohen intended to release the

camera from its usual constraints of crane and Steadicam, creating much more dynamic moves in which the car would come at camera at 140 miles per hour, for example- a stunt that would have killed an actual cameraman had it been shot for real. Cohen also wanted subjective coverage of the race, to allow the audience to see it and experience it from the driver's perspective. "We're always with the drivers in this film," stated Wassel. "There aren't a lot of traditional exterior blow-bys. Rob was more interested in moving the camera around the actors and seamlessly integrating them into the race; and those ideas dictated how the elements needed to be shot."

Sixty to seventy shots were planned for the Das Boot sequence, although more would end up in the final cut. Several months before the shoot, Illusion Arts began producing animatics in Maya and Electric Image as a means of illustrating, in motion, Cohen's vision of the race. "Ken Nakada, Michael Kory, Fumi Mashimo and I were all building animatics before we started shooting," noted Wassel. "We did full-blown 3D animatics for the entire sequence. Fortunately, we knew from the start what kinds of shots we were going to be doing- shots racing down the street with the actors in their cars, shots flying through a car's fuel injection system and so forth. I had those animatics while I was on set, so I could run through every shot with the stunt guys: 'This is what we need for the camera move. This is where we need to be.'" In conjunction with the live-action photography, filmed on a street in Hawthorne- one of several L.A.-area cities used in the movie- some shots of the actors in their cars were filmed on stage, where Waldemar Kalinowski built replicas of two sections of the street set, lit by Ericson Core to match the location photography.

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The start of the race is signaled by fire shooting out of a car's tailpipes as the drivers rev their engines- a practical effect rigged on stage by Matt Sweeney's crew. As Dominic throws his car into gear, the camera drops through the floor of his Mazda RX7, tracing down the stick shift and into the transmission system. The camera then moves through the transmission and into the engine where gears and rotors are seen churning as gas explosions fire directly at the lens. Finally, it launches through the exhaust, encountering the turbo system before bursting out the tailpipe, where it pans around and comes to rest on the rear of the vehicle just before the car peels out of formation.



Matt Sweeney and crew contributed numerous pyrotechnic effects, ranging from flames spewing out of exhaust pipes to the massive explosion of a supercharged racecar whose nitrous oxide tanks have been ruptured by gunfire.

Using a Revolution camera system, Wassel was able to get the camera into tight spaces inside the Mazda, beginning with a closeup on Vin Diesel's face, then following down his arm to the stick shift. Once the camera drops through the floor of the car and enters the drive shaft, the image transitions into an entirely CG shot created by Illusion Arts. "Some of the storyboards were rougher than others," said Wassel, "because the original board artists didn't really know what's under the hood of a Mazda RX7; so we had to do some research to figure out exactly what we were going to see when we took this trip through the transmission and into a rotary engine. It was up to us to define the shot, taking these three or four key frames that had been storyboarded and turning them into a shot that made sense."

For reference, Wassel and his team dismantled an actual Mazda RX7 engine, carefully examining and documenting every detail. "The transportation department was building a number of these cars without engines for stage photography," explained Wassel, "so they gave us the drive trains, and said, 'Have your way with them.' We cut open the transmission, hooked it up to an electric motor, and photographed it while it ran so we could watch the rotation process. We did some lighting tests to get Rob's and Ericson's feedback on how they wanted to light the inside of a transmission, because it's dark in there. Once we established a look that the director and DP were happy with, that pretty much set the tone for how we were going to light the engine interior."

Michael Kory fashioned animatics to illustrate how the shot would progress through the engine. "Michael's a CG expert, so we brought him in specifically to do this with Fumi," noted Wassel. "They did a ton of material study and worked at getting the surfaces to look metallic, like machines." Once inside the fuel-injection engine, the camera races through a gauntlet of complex moving parts. "We replicated what happens when a Mazda RX7 three-rotor assembly racing engine is running. The gas/air mix inside the engine is compressed, which ignites an explosion that fires off the rotors, making the car move forward- and that gave us a wonderfully dynamic visual to work with." Although the move through the Mazda engine would accurately reflect racecar dynamics, Kory and Mashimo invoked a bit of artistic license for the tailpipe

segment of the shot. “We had real tailpipe stuff, but it wasn’t very exciting-looking– it was black and icky. Mostly we were looking for some texture and representation of a muffler system, so we added baffle plates and streaks of light as the camera exited the exhaust pipe, then had the frame white out in the tailpipe’s flame as we switched back to real photography and the car took off down the street.”

Throughout the two-minute race, the camera not only explores the interior of a car’s engine, it also captures the principal actors at the wheel in dynamic camera moves, with backgrounds speeding past. Though shots of the actors could be done on stage, against bluescreen, in one of the racecar shells provided by the transportation department, Cohen’s intention to move the camera wildly around the drivers meant that a great variety and number of backgrounds had to be captured and integrated with those bluescreen elements. The solution was Circlevision, a variation on the Iwerks camera system developed years ago by Walt Disney Studios to film 360-degree movies for their theme parks. “We were familiar with the idea of Circlevision,” commented Wassel, “because Illusion Arts had created a matte painting for Disney several years back for a 180-degree triple-projection 65mm film. With Disney’s Circlevision, there were nine Mitchell cameras positioned in a circle and aimed up at mirrors that were angled out to cover 360 degrees. The rig was huge and weighed about nine hundred pounds– which was impractical for our purposes– but it was what sparked the idea, ‘Hey, we can do this.’”

To give Cohen the backgrounds he sought, the team determined that they needed a 240-degree view of the street that they could plug into the bluescreen shots. Not only would the field of view simulate that of the human eye, it would also allow Cohen to shoot any angle on the actors, knowing that a background could be plugged into the plate. Seeking something that was compatible with his Clairmont cameras and better suited to the production’s needs, Ericson Core hooked up with cameraman Jim Dickson, an expert on Circlevision who had devised his own rig. That unit, equipped with six Arri 435 cameras, and weighing in at just two hundred plus pounds, was comparatively lightweight and gave the filmmakers the requisite flexibility. Outfitted with 28mm lenses, the six cameras were mounted on a platform pointing into front-surface mirrors angled towards the street. Using the mirrors allowed the cameras’ nodal points to be as close as physically possible, and also enabled the cameras to fit onto a small aluminum chassis platform. The platform, about a foot and a half in diameter, had six base plates arranged in a circle and was bolted to a four-way leveling head that, in turn, was secured to a motorcycle sidecar– called a sidehack– designed for photography. “Since the motorcycle was very short, it fit in the blind spot of the Circlevision system,” stated Wassel, “so we could get a complete 240-degree clean plate.”

Preparations for the plate photography began early in preproduction and continued right up until shooting; but Wassel and a second-unit team captured the actual footage all in one night. “It was very tight and we were really cranking,” recalled Wassel. “We did a great many setups that night in Hawthorne. The first and second units had already been there for a week, and every night there were 350 kids on the street. They would come down, park their cars, and cheer as the cars sped by. I was terrified that with hundreds of cars lining the street, with their lights on and facing towards camera, there would be lens flare across the splits. We were

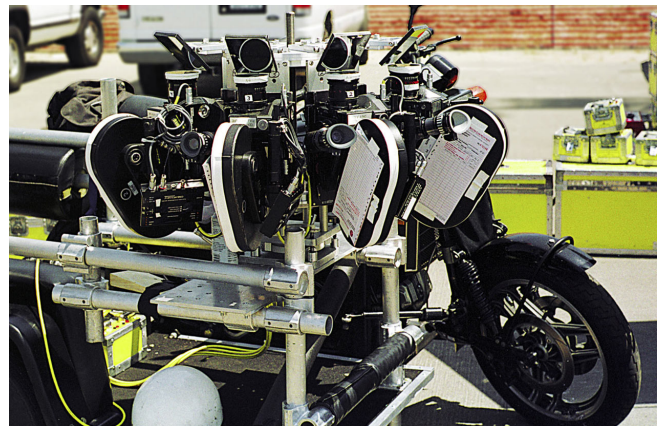
prepared to use a Rosco scrim- which looks like a very dense nylon window screen- on all the cars to knock the intensity of the headlights down; but luckily it wasn't a problem."

Lighting considerations did impose limitations on the shoot, however. "We were only lighting 1000 feet of street at night," related Wassel, "so at fifty miles per hour, we would only get about ten seconds of photography, and then we'd be out of light. The thing with Circlevision was that the entire street had to be lit for 360 degrees. With a combined horizontal angle of 249 degrees, and a vertical angle of 37 degrees, Ericson's night suns at either end of the street would flare the plates in cameras one and six. So those lights had to be repositioned for the Circlevision runs. However, the resulting black sky in those plates then needed to be replaced in post to match the first unit's photography."

In postproduction, the Circlevision plates were stitched together, tracked and stabilized. To accomplish that task for some fifty shots- most of them in the Das Boot sequence- Wassel turned to Hammerhead Productions and visual effects supervisor Thad Beier, who also helped with the motion control stage shooting of all the cars in the sequence. "We got Hammerhead involved because they are tracking experts," Wassel explained. "Hammerhead did all the Circlevision stitching and tracking- and those guys were spectacular."

For each shot, Beier and his team built the background plates by digitally seaming together the separate images from the six Circlevision cameras. But before the Circlevision frames could be blended, they had to be warped. "Each Circlevision frame is a rectangular image," stated Beier, "but if you take those rectangular images and seam them together, you don't get a nice curve, you get straight lines- and what you really want is a projection onto a cylinder. We had to deform the images to fit them onto a cylinder, then seam them together and motion-blur them." First the bounce had to be taken out of the plates. "The rig was very rigid, which was great since the cameras didn't move with respect to each other very much. Unfortunately, they moved a lot with respect to the world, because the motorcycle sidecar was bouncing all over the place."

Using proprietary 2D software, Beier tracked points in the middle and ends of the street in each frame. The two ends were relatively easy, since Beier could simply track distant streetlights. Views to the side were more challenging, because there was no consistent point to track to as the camera rig moved forward. "We were basically just trying to straighten out the line in each Circlevision



Backgrounds for the bluescreen work were shot with a multicamera Circlevision rig that supplied a 240-degree view of the street action. Resultant film elements were then tiled into a full digital environment that afforded tremendous flexibility in the designing of camera moves. Visual effects supervisor Mike Wassel worked with Illusion Arts and Hammerhead Productions on the shots.



frame,” said Beier. “We had all these little snippets; and in a typical 300-frame sequence there were probably forty or fifty points we had to track in order to get rid of the up-and-down motion to the side of the street. With six shots, 300 frames each and six cameras, that’s a lot of frames. That part was no fun. After we got it smooth, we had to deal with the other problem, which was lens flare from the big lights on the set. It was a hazy evening and because they could not matte-box off the camera lenses to get rid of the flare, we had to do some work to eliminate it.”

For an uninterrupted shot of cars approaching a laterally moving camera– which then swings up to follow driver Brian O’Conner (Paul Walker)– CG cars, produced by Illusion Arts, were inserted into an empty street plate, speeded up and stabilized by Hammerhead. As the digital racecars pass by, Hammerhead blended the shot into a bluescreen Circlevision stage composite.

Camera moves captured on the street during filming of the Circlevision backgrounds were replicated on the bluescreen stage when it came time to shoot the actors in their cars. “We had to track points on the cars and figure out how the cameras moved in real life on the street,” explained Beier. “Then we had to encode that in our motion control cameras on the set, and re-create the moves.” An LED witness system– designed by Al Miller of Lynx Robotics and used by Illusion Arts during filming of the background plates– aided the automatic tracking of reference points. “One of the classic problems with tracking is that your tracking marks end up motion-blurred, and it’s difficult to figure out where they are. Tracking software doesn’t like the out-of-focus goo that frequently results from the motion. With the LED lens, a strobe flashes for 1/5000ths of a second in the middle of the frame’s interval, leaving a perfectly crisp pin-sharp dot, which makes the tracking go a little easier because it doesn’t motion blur at all. In this movie, though, they were so out of focus, they looked like pretty darn big dots. Fortunately, they are monochromatic and were not all that hard to image-process away, although whenever we went through somebody’s hair, we got red density, which required lots of rotoscoping.”



Another digital amalgam begins with a line of cars– the lead one real, the others CG– speeding toward camera. The lead car engulfs the camera, which passes through its interior– pausing for a Circlevision bluescreen closeup of driver Dominic Toretto (Vin Diesel)– then out the rear window and onto the street, where it turns to look at the receding cars, all real at this point.

Ultimately, the Circlevision backgrounds made for a very fast stage shoot. "It was like having a giant cyc right outside the window," stated Wassel. "Rob could just shoot. He could put the camera anywhere he wanted and I could cover it- the whole street at 100 miles per hour. All we had to do was have our tracking targets in frame."

The first major shot in the Das Boot sequence to feature a handoff from street photography to stage photography occurs as four cars race neck-and-neck down the street. The camera begins on the sidewalk, moving parallel to the racecars, then moves into the street, pushing past the four drivers before coming to rest on Dominic as he starts to pull ahead. In the first part of the plate, filmed with a Steadicam on the motorcycle sidehack, the camera moves from behind a row of parked cars, crosses each racer's path, then flies into Dominic's RX7, riding with him for a pace. "The live photography from that shot was unbelievable," Beier related. "Mike Wassel and the second unit gave us great material to work with. We tracked the cars shot on the street and fed that data into a motion control camera, which we used to re-create the camera move on stage with Vin. We did some morphing to marry the two shots seamlessly, then added the Circlevision background behind Vin."

Immediately following that was a complicated move, dubbed 'the hinge shot,' which begins with a view of racecars on the left side of the street as they blast towards the camera at 140 miles per hour. The camera moves into the street, pausing momentarily between Dominic's car and another car blowing by mere inches away, then continues to the opposite sidewalk as Brian's car passes by, panning and picking up like a hinge movement as the car rockets past. Once in the car with Brian, the camera stays with him for a moment, capturing the other racers over his shoulder. "A lot of manipulation went into that shot," commented Wassel. "We started with a second-unit shot involving a Steadicam operator on a wheelchair dolly, very slowly crossing the empty street. The plate was 3D-stabilized by Hammerhead. Then they increased the speed of the footage one thousand percent, so we're flying down the street very quickly, and re-projected the camera into new geometry to get a nice, smooth move. Illusion Arts placed CG cars on the street so that in the final shot, we're flying the camera through a synthetic environment. At the tail end of the shot, we tied into the stage work, going into the car with Paul Walker, and inserting Circlevision behind him."



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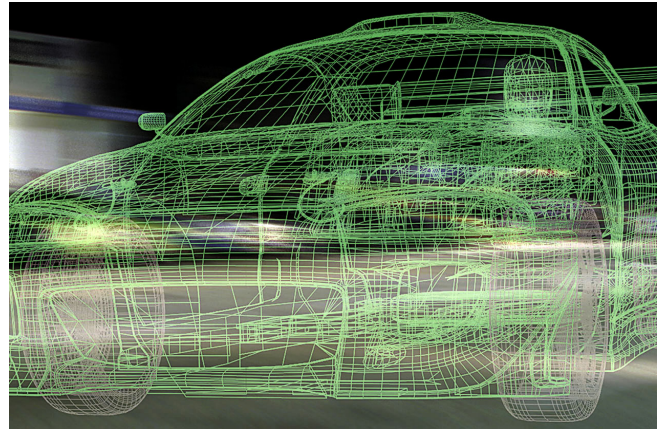


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Computer generating cars for the shot was new territory for the Illusion Arts team. “When the main-unit cars became available,” explained Wassel, “we got them on our stage, two at a time, and had them scanned and digitized by a crew at Poly Labs.

That gave us the surface detail of all the cars custom-built by production. We took the digital files from the production art department, and we were able to use the flat, computer generated shapes for texture mapping. That worked out really well.” Illusion Arts enhanced the CGcars’ credibility by incorporating environment reflections onto the models. “I shot Vistavision fish-eye reflection plates that we could reflect or shrink-wrap around the cars. Most of the time we were able to simply use the background photography itself and reflect it back into the car. Everything’s happening so fast that reflections were not the chief concern. The hard part was getting the paint to accurately match the environment. We did a lot of tests on how the glossy paint responds to light and how a car’s surface changes as you look down it. Look directly at the surface, and it takes on a less reflective quality. It’s more reflective when your incident level of sight lines are narrow, so we were trying to make sure we captured that.”

Jittery motion in the plate photography was smoothed out by Hammerhead. “The footage shot with the wheelchair dolly had been sped up by a factor of ten,” explained Thad Beier, “because the wheelchair wasn’t going very fast and they wanted it flying across the street. Of course the chair was bouncing all over the place—every tenth frame had a completely wacky motion that had to be smoothed out. But then it began to look very ‘stroby’; so I had to motion-blur the street to get that sense of motion. I tracked where the camera had gone, utilizing our camera tracking software, and sent one of my co-animators down to the street in Hawthorne to take some measurements long after we shot it. Once we tracked the camera’s motion, I built a low-rez digital model of the street, which was just a flat plate in the center and flat plates on the side, and texture-mapped each frame onto that simple model, rendering it with motion blur to get a sense of rapid movement. We could not just blur the frame uniformly, however, because every part blurs differently when the camera is moving—especially when it starts to hinge around. The only way to do it was to back-project each frame onto the model and render that with the camera move. If you look closely at the



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people on the street, you can see they're moving too fast. Fortunately, the red car in the scene covers them up very quickly, so they're not in the rest of the shot."

Hammerhead's tracking data was fed back to Illusion Arts so that when the CG cars were rendered, they were correctly based in virtual space in relation to the live-action cameras. "The cars crossing the street are synthetic blow-bys," stated Wassel, "and the only face you can make out is Brian's. When his car is far away from the camera, we used a generic CG driver; then, as the camera hinges around, we projected an image of Paul Walker's face onto the figure. The details are flying by so quickly that we were able to use film references of Paul instead of having him scanned. From that we morphed into a shot of Paul on the stage in front of a bluescreen. That was the only shot in the movie where we had to project an actor, and it was just for a few frames to tie the exterior shot into the stage work, with Circlevision behind him. As soon as the camera moves back inside the car, the cars are real again. Once the camera has picked him up, there's a rack focus from Brian to the car he's chasing. Although it's a subtle detail, the car we rack focus to is a real car from a Circlevision plate. Michael Kory did the rendering for that."

The full capability of Circlevision was put to the test in a following shot that involved a technically challenging 180-degree camera move around Dominic as he speeds down the road. "That was a shot Rob wanted in the sequence from day one," Wassel remarked. "From the standpoint of the effects, it's really the key shot of the sequence. The camera is on the street in Dominic's lane, looking at the cars coming right at it. We fly in through the windshield of the RX7, do a 180-degree dolly move around Vin Diesel and fly out the back of the rear window underneath the wing of the RX7, landing back out on the street as the cars recede from us. Originally, the shot was planned as a very graceful, slow move- about fifty seconds- taking more time as it circles around Vin; but it evolved into a much more frenetic move that was only four seconds long."

The final shot incorporated several elements, including two Circlevision plates- one going towards the car, one moving away from it- and a motion control dolly move of Vin Diesel on stage. "We had to cut away parts of the real car on stage to get as close to Vin as possible," recalled Beier. "It made me a little sad to take our saws to a beautiful RX7 - they don't make 'em anymore."

While the stage work for the shot took only a day, the composite work that followed occupied the better part of four months. "Most of the other shots we filmed on the stage didn't have to marry tightly with what was shot on the street," said Beier. "We'd just shoot a car and put a background behind it. In this case, though, we did have to match another car on the street, and it was hard to get all the pieces to work together in a continuous sequence. As we approach the car, we transition from the car shot on the street to the car shot on the stage, and they were lit completely differently- in fact, they were different cars! Details were different, so we had to do the transition in a way that wouldn't show that. We added lighting effects and blended the timing, even though the camera, as it was shot, sped up and slowed down a lot. It was one of the hardest shots in the film- and we spent twice as much time on it as the rest of the shots put together."

Rotoscope work also had to be performed for all the hundreds of spectators lining the streets and moving throughout the scene. “Most of what we did was just stop their movement,” stated Beier. “We’d take a single frame of them and track them in as the camera went by– because at the speed those cars are going, everything else that’s moving should look almost still. There were hundreds of different rotoscoping layers in the shot to get all of the pieces to line up together. Theresa Ellis did a tremendous amount of work on that.”

When Brian starts to fall behind, he fires up his nitrous oxide system– known as NOS– which floods the engine with combustible gas and gives the car a sudden burst of speed. As the system is activated, the camera follows the tube from Brian’s NOS tanks into the engine. “There’s no CG in that shot,” noted Wassel. “On our stage we filmed a real engine that we got from production. We built a mock-up of the underside of the car’s chassis and we had a mock-up of the car interior with the real NOS tanks in the back. We set up a motion control move; and when we actually got up inside the motor, we did a secondary build of an oversized combustion chamber. We opted to go that way, instead of CG, because building all of those wrinkled, bumpy surfaces in the computer would have been a pain. The underside of a car looks terrible– it has an undercoating all over it. The point here was to follow this bright shiny hose into the darkness, where it actually sprays into the engine. We thought it would just be easier to mock that up full size.” Added to the shot was the spray of NOS, done as a 2D particle effect. “The shot ends with the sparkplug firing, igniting the combustion. That’s all real photography filmed by our director of photography, Bill Taylor, and Adam Kowalski from our camera department.”

Cohen wanted a warp effect to illustrate the NOS-fired car’s sudden takeoff and acceleration. To achieve that, Wassel used a simple distortion of Circlevision plates aimed towards the end of the road.

“We weren’t looking specifically for an effect,” observed Wassel, “we were just trying to convey the idea of the world warping around Brian because he’s going so fast. We did a number of tests on how this distortion effect would animate. Getting that snapping feeling was crucial because it was more about the animation of the effect, less about the effect itself.” Rebecca Marie at Hammerhead handled the distortion.

Upon reaching speeds upwards of 150 miles per hour, Brian’s car begins to fall apart. Bolts pop and a metal plate drops from the floorboard, generating a shower of sparks; then the plate breaks loose and flies back into the camera. On stage, Matt Sweeney and his crew practically rigged shots of the bolts popping, the shower of sparks and the plate dropping. Sweeney also contributed sparks for second-unit street work involving the metal plate, while Illusion Arts provided a CG version of the plate for the shot of its flying toward camera.

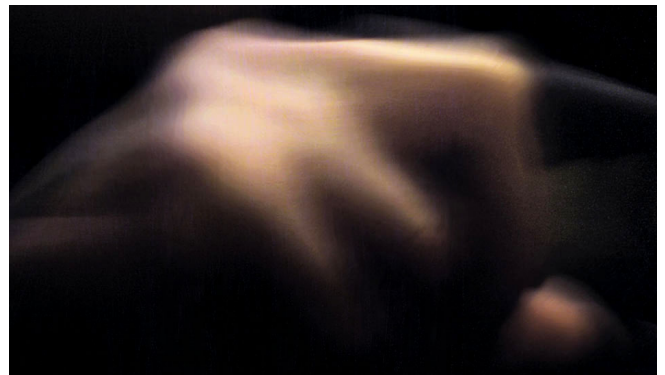
At the end of the sequence, a swift pullback reveals all of the cars crossing the finish line, with Dominic narrowly edging out the others. “Although the cars crossing the finish line were photographed for real,” related Wassel, “it didn’t happen in that kind of time frame. It was a fifty-foot Technocrane pullback that happens in eight frames. We filmed Brian’s and Dominic’s cars running through, then moved the camera position in a very slow, safe way and let the other two racers come through from the second camera position. Then we just tightened all that empty space in the cut, applied a little camera shake and dropped in downtown L.A. behind them at the finish line– the only matte painting in the whole show.”

Immediately after the Das Boot race, Brian and Dominic are confronted by a rival racing gang that shoots up Brian’s car, causing his NOS tanks to explode. To capture the blast in-camera, Sweeney’s crew built a special rig for the Mitsubishi Eclipse. “We did something a little different from the standard car explosion,” stated Sweeney. “We launched it into the air by putting black powder lifters inside four little closed cannon mortars. We packed wet sand on them and set the four lifters beneath a big steel plate welded under the car. Then we set the car down on top of the sand mortars so that when we ignited the black powder lifters, the car got high up in the air. For the actual explosion, we rigged a couple of naphthalene bombs, which are mothball flakes with black powder mixed in. We also added a couple of gallons of Roger George Blue Fire fluid, vaporized it, and blew that up inside the car in the midst of this explosion. That gave us a nice big blue flash all the way around the car to represent the nitrous oxide going up.”

As the story unfolds, Brian’s undercover investigation reveals that Dominic’s racing gang is, in fact, responsible for the big-rig hijackings. When Brian attempts to take Dominic in, the two



At the start of a major race, the camera focuses on Toretto and then drops through the floor of his Mazda RX7, traversing its transmission and engine before passing out the tailpipe. Aside from live-action at the head and tail, the shot was entirely computer animated by Illusion Arts.



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end up racing down a stretch of deserted road towards a finish line marked by a set of train tracks. Unbeknownst to either driver, a train is speeding towards them on the tracks.

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The train race did not employ Circlevision, but was filmed as a straightforward in-camera sequence at Terminal Island in Long Beach. The scene begins with a shot of a red traffic light; then the camera tilts down as the light changes to green, with the two cars reflected in the light's glass lens. Wassel shot a high-angle fish-eye view of the cars moving into frame, stopping, then leaving frame. That was composited into a Vistavision plate of the light, with the camera move added in post.

As the men rev their engines, Dominic's Dodge Charger performs a wheelie, its front tires leaping off the ground before speeding off. The stunt was achieved with a rig built specifically for the scene by the practical effects crew. "We cut a couple of holes in the floor of the car," explained Sweeney, "and put in a couple of arms with wheels on the end, with a big hydraulic ram on them. When you put air to the ram, it pushed the car up and made it do a wheelstand." Although most of the rig would be hidden by camera angles, Illusion Arts had to later remove a small section of it digitally.

After the blast-off, the camera travels through the Dodge Charger's instrument panel and into its malfunctioning engine bay. "You hear this clunky engine sound," related Wassel, "and then we push through the instrument panel and watch the motor throw a rod and break. The engine work was all CG, done at Illusion Arts. Because in the real world that engine and that car do not go together, we had to rent the engine. We got it over here, photographed it, camera-mapped it, and built a 3D version of it. We then built an environment for it that we could fly our virtual camera through. We had the practical instrument panel that we could photograph and fly through in CG, but we had to create part of the interior, part of the underhood structure of the car. The explosion animation was based on real photographic elements staged by Matt Sweeney's crew. Fumi Mashimo did all of that work."

When the train sequence was edited, the filmmakers decided they wanted the cars and the train movement accelerated to ramp up the action and heighten the drama, necessitating further effects work. Given less than two months to deliver a finished product, Wassel enlisted the aid of Digiscope and supervisor Brad Kuehn to handle some thirty shots in the sequence. "The movie had a very fast pace to it," Kuehn recalled. "The editors would get on the Avid, and even if they had the shot that they wanted, they'd say, 'That shot was fine; let's just make it 200% faster.' You can achieve 200% faster at the lab, but it can look skippy and you see jittering from frame to frame. All of a sudden it looks like you're in an early black-and-white movie, and that wasn't what the production wanted. The idea wasn't to speed up the camera motion; it was to make the train and the cars go faster."

Digiscope first tracked the shots, then utilized Inferno software to perform frame-by-frame animation to speed up the action. “We needed to see how the camera moved,” stated Kuehn. “Unfortunately, it’s not like we could just pick a point and track it through the entire shot. We would track multiple points depending on how they came in and out of camera. Then we ran stabilization programs on the image, saw what the data was and started tracking by hand when it didn’t look right. It could take as many as three or four renditions. For example, if the shot was 100 frames long and they wanted it to be 60 frames, we would run a frame-averaging algorithm to speed it up. The algorithm looks at the two frames and starts selecting what goes into the new image. There’s quite a lot of math that goes into the algorithm- and when it’s wrong, it’ll leave strange artifacts. All of a sudden we might get weird blurs, so the artist would have to go in and clean those up by hand. Once the artist got to a point where the speed looked good, we’d go back to the original camera data we’d obtained from the tracking and reapply that, as well.”

As both drivers realize that they cannot stop in time to avoid the train, they ramp up their speed even more. Side by side, the cars break through the railroad crossing arms- a stunt filmed in multiple takes using forty sets of breakaway crossing rails built by Matt Sweeney’s crew- and leap across the tracks mere inches ahead of the train. Production provided Digiscope with two plates of the shot. “The second unit shot separate plates of the train going through frame and the cars breaking through the barriers,” said Kuehn. “We had to put the two pieces together, which was very difficult because there was a huge amount of smoke and exhaust behind the cars. You can roto cars out, but you can’t roto smoke, because smoke is transparent. What you’re left with is a composite that takes what’s visible through the smoke and combines it with the train. However,



For a climactic scene in which O’Conner and Toretto attempt to beat out both each other and a speeding train, Digiscope combined separately photographed train and car elements.



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now the train looks transparent. We ended up having to roto the cars out separately and composite them with the train. Then we feathered stock smoke elements in behind the moving locomotive.”

For a climactic scene in which O’Conner and Toretto attempt to beat out both each other and a speeding train, Digiscope combined separately photographed train and car elements.

Digiscope’s work on the shot included anima-tion to marry the two plates together. “As the cars broke through the crossing guard arms,” explained Kuehn, “we took the existing pieces of debris and collided them against the train, adding some more debris here and there. That was accomplished by the artist simply rotoing the different pieces of debris, finding an appropriate stock element, adding paint, and hand-animating it. The artist experimented with bouncing bits off the train at different speeds and figuring out how to make them play with the speed of the car. The other thing we had to do was resize the train a little bit and speed it up to make it more impending. Even though we synced up the timing of the train to the racers, the shot didn’t feel dangerous enough. To make things more dynamic, we cheated the train’s size to make it a little bit bigger, make it closer to the moment of where, in reality, it would have smashed right through the cars. Another subtle effect was reflections from the train that we threw onto the top of the cars. In real life you probably wouldn’t see any such reflection from that angle, but we did a lot of that kind of massaging to raise the level of excitement.”

Another Cohen-mandated addition to the train sequence was a series of ten shots depicting the two characters inside their cars in a kind of slow-motion reality. Hammerhead handled the shots, which were designed to serve as dramatic counterpoint to the blurred speeds around the racers. “It’s a very subjective perspective,” said Wassel. “A lot of the technical advisors talked about how your brain starts over-clocking and things tend to slow down when you’re traveling at 140, 150 miles per hour. Editorial did a rough test on what pieces of film they wanted to use, how they wanted to establish the pacing of those effects, and then Hammerhead went to work, trying out different things to see what Rob would respond to.”

The perspective shifts from inside the characters’ isolated and slowed reality to the chaotic, fast world outside the cars. Cohen dubbed the slowed-down images ‘Becky-vision shots,’ in reference to Rebecca Marie, who executed them. “Most of them were fairly easy to do once you came up with the proper script to run,” commented Thad Beier, “but there were a few where the dissolve from one frame to the next would accentuate Vin Diesel’s nose in a way that was unattractive, or part of a window would turn black. Becky would have to go in and hand-paint those frames to get them to work.”

Both racecars clear the train with just seconds to spare. However, before Dominic can recover, he is broadsided by an eighteen-wheeler coming off a side street that sends his car flying and twisting over Brian’s, then smashing to the ground. A POV from inside Brian’s car as the Charger flies over it, mere feet away, was, incredibly, captured in-camera with stunt drivers. “We filmed a shot of the real truck pulling out,” said Matt Sweeney, “then we brought in a new truck set piece with a single-rail pipe ramp bolted right into it, tapering off in the direction the car was coming at it. So as the Dodge came through the front of the truck, it was raised up in the air. Chris Tuck, who was driving Paul Walker’s Supra, and Tim Trella, who was doubling for Vin Diesel in the Dodge, did a couple of passes to get their speed up and to get their

synchronization with the cameras. Then Mic Rodgers put an Eymo camera down in the road right behind where the car was supposed to land. When we rolled camera, Tim hit the ramp and the Dodge went up into the air and twisted; then Chris came along parallel to it, moving over and darting underneath as it went over him. Then the Dodge landed and bounced onto the Eymo- that's how close the landing was- giving us that one killer shot of the car coming right at camera. They just did that once."

The physical effects team also built a car interior designed to collapse around Vin Diesel. "Andy Miller and his guys built a whole soft aluminum and lead car interior," said Sweeney, "with big hydraulic rams and pushers on the exterior for crushing it. We pressed a button and the whole thing caved in around Vin- breakaway glass, the windshield, and the car body. We shot it on stage in front of a bluescreen and it really looked good."

In the film's concluding shot, Brian hands his car keys to Dominic, who has miraculously survived the crash, then turns away, walking toward camera as the shot gets slower and slower before fading out. The final shot offered up one last challenge for the Hammerhead team. "They originally ran that shot in real time," explained Beier, "and although it was the right emotional ending to the movie, it was very abrupt. So we decided to slow down Paul Walker to give it a sense of closure." Making the shot look as if it had been filmed that way required some intensive rotoscoping and a special application written by Beier to morph the actor into the scene at the desired speed. "Most morphs you see go from one image to another to another, and you see a short break in the intermediate frames because things are warping in different directions. It's a very linear kind of thing and doesn't look smooth. What we did was a smooth morph through several hundred frames, blending from one to the next and the next, to slow down time as much as we wanted while still retaining a perfectly crisp image of Paul Walker. The rotoscoping of Paul's hair was a nightmare, though- it was just all over the place. All those little intricate beach-blond curlicues had to be individually traced - and they needed this shot in about four days. It was fun, though, because we were able to give the filmmakers something they didn't think they had."



Both cars make it past the train in another Digiscope composite.

The Fast and the Furious opened to exceptionally good reviews, marking the second time in his career- the other being with Dragon: The Bruce Lee Story- that Rob Cohen had elevated a project from its B-movie origins to a critical success. The film also marked yet another recent foray into the realm of virtual cinematography, with digital tools being used to enhance live-action elements in addition to providing visual effects sequences.

“Photography takes time,” Mike Wassel commented, “and if you can do it without waiting for a first-unit crew, the producers are much happier. We were able to do a lot in a very short period of time with just the camera in combination with CG, and end up with real photography synthetically blended and generated. That’s definitely going to be the next step in terms of what production requires.”

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Immediately thereafter, however, Toretto’s vehicle is struck by a huge truck. Matt Sweeney and his team rigged the car to flip up and over O’Conner’s.

JOWLY GREEN GIANT

ARTICLE BY Joe Fordham



In Shrek- PDI/DreamWorks' second venture into feature-length computer animation- a grumpy ogre and his donkey sidekick embark on a quest to save an imprisoned princess.

The jowly green giant of PDI/DreamWorks' digitally animated feature, Shrek, had every reason to be jolly. In his opening weekend at the boxoffice, the barrel-bodied bogeyman accrued in excess of \$42 million in ticket sales, and within two months had raked in another \$200 million, making him the summer's hottest star. Although, technically, the giant was a grumpy, slime-loving, bug-eating ogre, the metaphor held true for appreciative critics, pun-hungry press-hounds and audiences, young and old: Shrek was a monster hit.

Based on the children's picture book, *Shrek!*, published in 1990 by veteran New Yorker cartoonist William Steig, the computer generated blockbuster was a simple fairy tale, if a little skewed. Take one grouchy ogre in a desolate swamp, foist a boat-load of homeless fairy tale characters into his domain, add a fast-talking, freeloader Donkey and a diminutive Lord Farquaad- who instigates the swamp invasion while cleansing his magic kingdom, Duloc- and the story becomes a classic quest. Shrek strikes a bargain with Farquaad to rescue the nobleman's beloved Princess Fiona from a fire-breathing dragon in return for his lost peace and quiet. The resultant adventure not only tests the ogre's mettle, but ultimately leads him to fall in love and challenge his preternaturally grizzly nature.

Shrek's colorful characters, gross-out humor and all-action plot appealed to children, while its refreshingly humanistic themes and sly spoofing of genre icons amused and surprised older viewers. The movie's triumph was the latest in a string of animated successes for DreamWorks co-founder and animation guru Jeffrey Katzenberg, coming on the heels of *Antz*, PDI/DreamWorks' inaugural computer generated feature. Early concept work for Shrek, however, began in 1996- long before *Antz* was released- when producer John H. Williams presented the idea to Katzenberg on the advice of his kindergarten-aged child. The project first took shape as a hybrid live-action/stop-motion/CG-animation vehicle for Saturday Night Live comedian Chris Farley, its development initiated by animation director Kelly Asbury, a storyboard and layout artist who had worked with Katzenberg on *The Little Mermaid* and *The Prince of Egypt*. Asbury was joined by production designer James Hegedus and co-director Andrew Adamson, who had been an associate of Hegedus' as a visual effects supervisor on the last two *Batman* films.

"When I joined Shrek in 1997," said Adamson, "I had just finished *Batman and Robin*, working as a visual effects supervisor under John Dykstra. That show had a lot of integration between



Lord Farquaad, the dwarfish master of the realm, seeks advice from a talking mirror.



At Farquaad's insistence, scores of fairy tale creatures are rounded up and dumped in Shrek's hitherto peaceful swamp.

miniatures, live-action and CG- there were scenes with actors in miniature sets, with CG motorcycles, CG vehicles and CG characters- and I came away wanting to try combining all those media, knowing that it hadn't been done before. James was working with Kelly as a visual consultant at that time and, coming from live-action, had a similar desire; so we ended up designing a look for Shrek in miniature."

The filmmakers planned to shoot a pastoral fairy tale environment as proof of concept for Katzenberg, combining miniatures, painted backdrops and matte paintings, into which Farley's motion-captured performance as Shrek could theoretically be inserted. After shopping the concept around, they turned to Syd Dutton and Bill Taylor, co-founders of Illusion Arts. "We were commissioned to do two shots," recalled Dutton. "James and Andrew came by and we worked together designing the shots as eight-by-ten-foot tabletop miniatures. We decided they should be like those Easter egg boxes, where you look through and see different layers: one background being a forest with a field, another with a castle. Our master miniature builder, Lynn Ledgerwood, built miniature hills, a couple of big gnarly trees and foreground foliage, using half-scale for the foreground and quarter-scale for the midground. He carved the terrain and the trees out of styrofoam, and dressed the foliage with silk leaves that he got from a nursery. James designed the far background, which I painted as a cyclorama on a four-by-eight-foot piece of masonite. We shot a motion control push-through and reveal, and added a bit of cloud movement and waterfall animation- done with a mechanical gag, similar to the old Hamm's beer signs- as an additional exposure on a separate motion controlled pass."

Although Katzenberg reacted enthusiastically to the tests, art-directed and lit to convey an appropriate storybook richness, the miniature approach was finally deemed impractical in light of other resources at hand. "Using miniature backgrounds was totally feasible," asserted Adamson. "What you get for free with miniatures is texture, atmosphere, shadows, dust- so we thought it would get us there quicker. But PDI was just finishing *Antz* at that time; and through a lot of hard work, they had created a very good pipeline for doing an entire CG movie. To break the pipeline at that point was not appropriate within the structure of the studio. In retrospect, going all-CGI was a good decision because it allowed us to include a lot more life in our backgrounds- moving trees, moving grass- which is hard to do in miniature."

With the miniature approach set aside, Hegedus took leave of the project, which continued to undergo a change of guard. A tragic blow came in December 1997, when Chris Farley died of a heart attack at the age of 33. While producers considered their options, including recasting, Kelly Asbury took up the co-directorial reins of DreamWorks' cel-animated *Spirit: Stallion of Cimarron*. Story artist Vicky Jenson took Asbury's place on *Shrek*, making her directorial debut alongside Adamson.

With the decision made to produce an all-CG version of *Shrek*, the task of adapting Steig's book to the screen fell to a team of four screenwriters and a twenty-eight-member story department at PDI, led by story co-heads Randy Cartwright and David Lowery. "The thing about Steig's book," said Adamson, "was that it wasn't really a linear narrative. It was more a study of this character, Shrek, and his inverted way of looking at the world- at one point, for instance, he has a nightmare about children dancing around with flowers and butterflies. This gave the story an irreverent tone for a fairy tale, because it took a traditional villain and treated him like a hero."

A Steig subplot involving Shrek's parents ousting him from the family swamp was exchanged for the more dynamic and subversive storybook invasion. Other book elements, including Shrek's encounter with a distinctly bovine dragon, were retained as inspiration for the more plot-driven feature film.

Long before the script was finalized, Katzenberg started to secure vocal talents for the production, casting Eddie Murphy as Donkey and Cameron Diaz as Princess Fiona, with John Lithgow lending his Shakespearean vocal talents to Farquaad. The task of filling Chris Farley's shoes as Shrek fell to fellow Saturday Night Live veteran Mike Myers. "Mike fell in love with the theme of the movie," commented Adamson, "and he really helped us in developing the character. Eddie was more of a known quantity in his characterizations, coming from his amazing work in *The Nutty Professor*; but with Mike, we knew he could become a wide range of different types, as we've seen in his *Austin Powers* movies. So we went into the studio and started playing. Mike did one voice for Shrek for a while, then realized it was the wrong way to go; so we rerecorded about twenty minutes of the movie that we'd already done. It was very much an Evolution."

Mike Myers head of layout Simon J. Smith and assistant editor Christopher Knights pitched in as three blind mice. Knights also supplied the voice of Thelonious, and other PDI artists voiced additional supporting roles- Conrad Vernon as a gingerbread man, Chris Miller as Geppetto and Farquaad's magic mirror, and Cody Cameron as Pinocchio and all three little pigs. Each voice artist recorded his lines separately, both to accommodate artists' schedules and to allow for a clean audio mix. Editor Sim Evan-Jones assembled the performances into the form of a radio play, juxtaposing takes for nuances of inflection and trimming repetition. Storyboards were digitized and cut against the track, pacing the action to allow the directors to build the dynamics of each sequence, sometimes restructuring and streamlining the story. The story reel- which refined the narrative into thirty-one sequences and 1288 shots- clocked in a few minutes over the final ninety-minute running time.

As the structure of the movie emerged, James Hegedus rejoined the project and began to pool visual references ranging from Victorian fairy paintings to storybook illustrations- including the art of Edmund Dulac- to the fiction of The Brothers Grimm. "We all share a collective memory of fairy tales," observed Hegedus. "The references are there, whether you know it or not.

We tried to stay fresh by looking at real-world reference, as well. When DreamWorks were researching The Prince of Egypt, for example, they sent people to Egypt. The ironic thing was, we weren't researching a period film, so we had nowhere we could visit. We took a trip up to Hearst Castle in San Simeon at one point to get a sense of the opulence of Duloc; but this was really a fairy tale, independent of time."

One early innovation was inspired by two of Adamson's favorite art references, American illustrators Grant Wood and N.C. Wyeth, whose lush storybook illustrations suggested an Impressionistic palette. "When you look out of a window into natural daylight," Adamson noted, "shadows seem to take on a bluish tone, mainly because what your eye perceives is based on the warmth of the sun and sky. Impressionist painters heightened that effect by pushing the colors in paintings, creating this imaginary reality. A lot of storybook illustrators, like Wood and Wyeth, carried that over into their fantasy illustrations."



Almost all of the film's flame effects- including those emanating from a fire-breathing dragon guarding the princess- were produced digitally via volume rendering techniques.



Shrek strives to rescue his companion from the dragon, a love-struck female smitten by the talkative donkey.

Adamson discussed his visual concept with visual effects supervisor Ken Bielenberg, who jetted in to the Glendale studios from PDI's home base in Palo Alto to advise on feeding art into the company's digital pipeline. Bielenberg supervised the creation of what became known as a 'complimentary shader' for Shrek's virtual lighting package, which produced a radiant lighting effect by introducing chroma to the shadows. "Traditionally in computer graphics," Bielenberg explained, "if you hit an object with, say, a yellow light, the yellow will fall off through browns to black. Andrew didn't want that. He wanted to go from yellow, through magenta, to purple, to blue. So instead of just one color in the shadows, we had about four, blending through as the light attenuated to black." While Bielenberg divided his attentions between this and other technical hurdles looming early in production- including interactive fire for Shrek's encounter with Fiona's dragon, realistic fur for Donkey and greenery for pastoral scenes- work continued on the broader challenges of building environments and characters.

The character of Shrek began as a series of two-dimensional conceptual renderings that refined William Steig's loose-line pen-and-ink style. Shrek took three-dimensional shape in the hands of character designer Tom Hester, who sculpted some fifty clay maquettes in various scales. Final sculptures, cast in resin, included full-body Shreks standing six to eighteen inches tall and more detailed six-inch character studies of the ogre's head. "Theoretically," explained Adamson, "we could have gone straight from paper into the computer. There are certainly people so familiar with digital modeling tools that they can work as fluidly as Tom can with his clay- our supervising animator Raman Hui, for instance, very effectively designed a lot of our secondary and background characters that way. But Tom's natural way to communicate is to sculpt. He could turn around two or three rough sculptural sketches in a day, so it was an obvious way to work."

Despite the fantasy nature of the lumpen lead-ing man, his was a humanoid form; and so, Hester's sculptures catered to problem areas endemic to three-dimensional digital animation of anthropomorphic characters. "Shoulders are one of the most difficult areas to set up in CG," Adamson observed. "They contain multiple direction points and, because there are so many overlapping muscles, if the character is not set up correctly, the shoulders will collapse. So we kept Shrek very true to human anatomy. Tom's father is a doctor, so he had a good working knowledge to build from." Shrek's double chin also became an area of concern, requiring some paring back of fat to allow the character to look down.

After scanning Hester's maquettes, character co-supervisor Lucia Modesto and lead character technical director Richard Walsh set up animation controls based on PDI's 'Shaper' system. Walsh had begun developing Shaper as a muscle and facial animation program for commercials in the late 1980s, and oversaw its first cinematic application in the 1996 alien invasion feature, *The Arrival*. In essence, Shaper took PDI's earlier animation program, *Skin*, and inverted the technology. Instead of building deformation boxes around the surface of a character, then moving the boxes to animate it, Shaper deformed the character from the inside out- starting with the skeleton, then building up layers of muscle, fat, skin and clothing. Shrek was ultimately comprised of ninety muscles, capable of being deformed by 836 shapers- including 180 facial controls and 585 body controls. During key-frame animation, Raman Hui, a team of five directing animators and twenty-two animators employed variations of inverse kinematics, which

allowed models to follow through as if chained together, and forward-driven kinematics, which involved hand-tweaking models joint by joint.

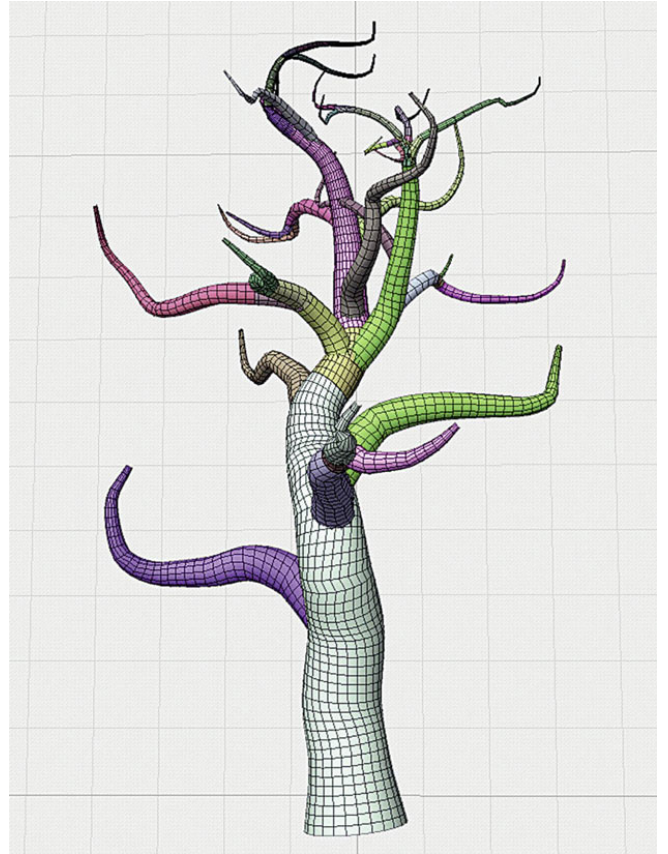
Under Hegedus' lead, costume designer Isis Mussenden designed Shrek's wardrobe to reflect Steig's illustrations, translating vibrant colors more suited to the graphic print medium to earthier hues and organic textures. The character's day-glo red britches became a subtle gold and burgundy plaid, and his vibrant blue tunic became ivory-colored burlap with a leather belt and a crocodile-skin vest, smoothed by age at the shoulders. Mussenden supplied PDI digital cloth designers with swatches to help them imbue real-life sheen to Fiona's velvet dress and Farquaad's satin cape. Designers, modelmakers, texturers and animators also met with an armor specialist to examine and get a feel for ogre ironware.



Shrek discovers Princess Fiona in a castle tower. Unlike most of the characters in the film, which were broadly drawn, Fiona was designed to look essentially real, though somewhat stylized.



Thousands of trees were digitally 'grown' in 3D space, then dressed with billions of CG leaves and texture-mapped bark.



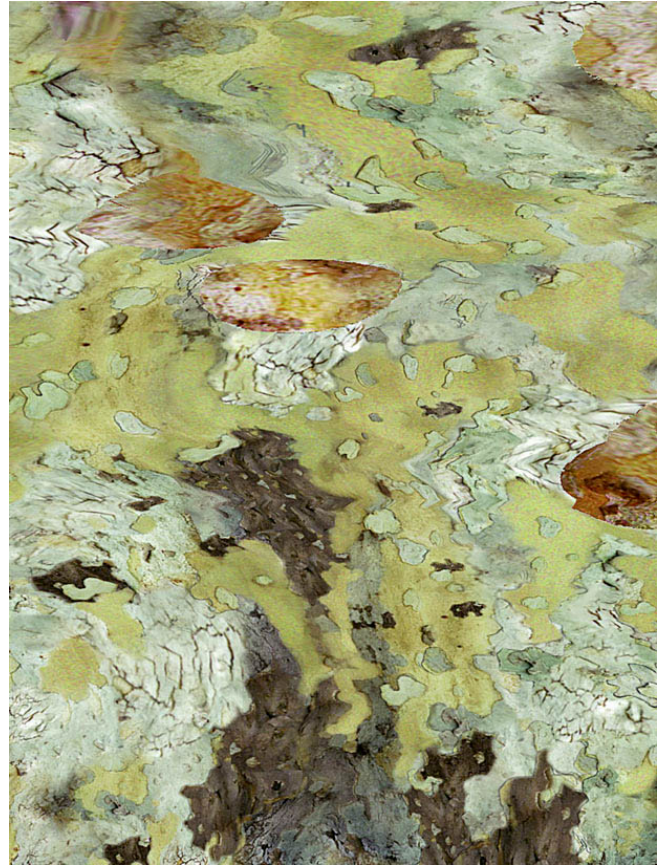
Thousands of trees were digitally 'grown' in 3D space, then dressed with billions of CG leaves and texture-mapped bark.



Thousands of trees were digitally 'grown' in 3D space, then dressed with billions of CG leaves and texture-mapped bark.

Less tangible aesthetic criteria came into play in the design of Princess Fiona, who appeared in Steig's book as a shock-haired redhead with an extremely long and pointy nose. While the decision was made early on to make Fiona the most human-looking character in Shrek, Cameron Diaz's vocal performance characterized the princess more as feisty fighting figure than traditional waif. Hester brought the character through a range of physical types, while Jeff Hayes supervised her modeling and David Doepp and Bert Poole dealt with surfacing issues. "The design process involved a lot of people," noted James Hegedus, "and the ultimate approval came from Jeffrey Katzenberg. If you laid out all of our designs, you would see Fiona's hair start out huge, like Farrah Fawcett's, then go short; you'd see her breasts grow big, then shrink. We had body parts of every actress in the world in there at some point. The intent was to find the representative stylization that we could believe. I give great credit to the makers of Final Fantasy for what they achieved with their beautiful surfacing and rendering of photorealistic humans, but I think the performances in that film were so photoreal they took the average movie-goer out of that reality. We made a conscious decision not to go that route, making sure we had an attractive character that resembled a human, but was still somewhat stylized."

Stylization was more obvious with Farquaad, his disproportionately inflated head emphasizing his short stature- a major plot point and source of humor in the tale- although the pint-sized despot remained, fundamentally, anatomically correct. "Facially, I was quite pleased with Farquaad," said Adamson. "His facial shape was rather extreme, but when he grimaced you saw all of the wrinkles and frown lines and, in particular, the definition of the sternocleidomastoid muscles in his neck connecting the sternum to the back of his head. Tom Hester worked very closely with Richard Walsh to make those muscles move in a realistic fashion."



Thousands of trees were digitally 'grown' in 3D space, then dressed with billions of CG leaves and texture-mapped bark.



In a parody of the 'bullet-time' effect from The Matrix, Fiona freezes in midair as the camera rotates around her during a fight with Robin Hood's merry men.

Animators studied live animal reference for Shrek's sidekick, Donkey, who was given a slightly enlarged head to incorporate expressive brow movement and a mouthful of big teeth inspired by Eddie Murphy's exuberant vocal performance. Donkey's legs were also deliberately shortened to give the character a perpetually happy-go-lucky, puppy-dog gait. Ken Bielenberg's effects team designed a fur shader armed with flow controls that allowed layering and grooming of the fur across Donkey's body. Additional applications of the shader included the production of eyebrows, beards, moss and frayed threads dangling from Shrek's tunic.

In an unwelcome plot twist for Donkey, Fiona's guardian dragon initially appears threatening, but then begins to exhibit an unexpected feminine side, falling in love with the chatty mule and becoming more vulnerable. "We played around with some traditional lizard types," recalled Adamson, "and gave her a hint of eye shadow and lipstick. One of my favorite dragon designs was a big saggy thing with earrings, very voluptuous and overweight, with rolls of fat down her arms; but that was impractical to achieve since she was a secondary character."

The addition of ancillary characters late in the project called for last-minute rethinking of characters already designed for background use. Bystanders in Duloc were multiplied to crowds numbering up to 1500 persons for a tournament scene and Farquaad's third-act wedding. These models were later adapted to play a small group of ogre hunters seen in closeup in the opening of the movie, then modified again into thirty-one storybook archetypes featured in the first-act swamp invasion. To animate the throngs, digital artists created some 200 motion cycles for 450 variations of generic Dulocians- interchanging heads, bodies, costumes and hairstyles, as needed.

Shrek's fantasy characters populated multiple environments that emerged from the art department as blueprints. Artists and technical directors then determined 3D parameters, allocating z-depth for aerial perspective and selecting areas that could be conveyed more simply with 2D matte paintings, supervised by Michael Collery. Modelmaker Facundo Rabaudi built physical models of the more intricate settings, such as Fiona's tumbledown gothic castle perched above a lava moat and an abandoned mill seen in the third act, both art-directed by Douglas Rogers. The wood and foamcore mockups assisted Andrew Adamson and Simon Smith in storyboarding action, and also helped plan 'flyaway' CG set pieces to facilitate camera angles, allowing for more efficient modeling and rendering. Digital set builder Sylvain Doreau then blocked out rough 3D digital representations of sets for the layout department, referencing concept art and storyboards, and laid the groundwork for modeling and surfacing environment teams.

The city of Duloc would become a humorous and pointed example of an environment designed to reflect a character's personality, its giant thrusting tower evidence of the tiny Lord Farquaad's insecurities, and its squeaky-clean cobblestone streets a jab at the popular packaging of fairy tales. "There was a pun there, naturally, about any theme park visitation," commented James



Their journey almost complete, Shrek and Fiona gaze across the verdant countryside at Duloc, the

Hegedus. "We also incorporated elements of the pre-World War II architecture of Albert Speer, the architect for Hitler, whose monumental structures, beautiful proportions and minimal ornament were

fortress city of Lord Farquaad. Divergent design influences for the city derived from theme park environments and period fascist architecture.

designed to proclaim, 'You serve the greater whole.' When you couple that with, 'Come be happy at our kingdom,' there are interesting conflicting intents." Another side to Farquaad's persona originated with Jeffrey Katzenberg, who suggested dressing the tyrant's bedroom with mid-twentieth-century bachelor-chic décor. "It was a fun exposé of Playboy camp, a great contradiction to the clean, austere Duloc- and it was also quite revealing about Jeffrey!"

For the countryside surrounding Duloc, where the majority of the film's action takes place, Ken Bielenberg oversaw the creation of a 'digital greenhouse' to supply Hegedus with varieties of trees to set the mood for scenes throughout Shrek's journey- redwoods emphasizing strength, birch representing solitude, sycamores for happiness. Bielenberg considered modeling pastoral landscapes by using a volumetric rendering solution known as 'Texels' - procedurally generating and tiling volumes of 3D data as painterly illusions of texture. When this approach proved too unwieldy, Bielenberg's team instead adapted the multifarious fur shader under development for Donkey and combined this with an instancing technique, creating virtual copies of grass and leaf models, and 'growing' vegetation into 3D space. Texture artists described swathes of grass or volumes of leaves on branches, indicated depth and a pattern of movement, and the shader filled the matrices from this minimal data.

Scott B. Peterson, one of five effects leads working under Bielenberg, created a custom tree system for the Shrek nursery. Peterson analyzed tree genus, translated branch shapes into growth patterns, then procedurally grew branches. Tree trunks found in Shrek's swamp, featuring gnarled root structures exposed above ground, were hand-modeled. Peterson would then graft the appropriate canopy onto each trunk. "We were always concerned about the connection of objects to the ground," Bielenberg related. "We learned from Antz that this can really throw off the CG if it's not right." Digital foliage- a total of 28,186 trees and three billion leaves- was ultimately featured in 508 shots.

Peterson also played a part in adapting PDI's fluid animation system, 'Flu,' to cater to the peculiar viscosities of liquid on display in Shrek- notably in an early scene in which Shrek takes his morning shower under a rain of mud. "Scott 'volunteered' to dress up in a rain slicker," said Bielenberg. "We took large quantities of mud mixed up with water and dumped it on his head, for technical reference. I'm always telling my animators, 'Go do it.' They tend not to because they're worried about deadlines; but all the reference and conceptual work you do ahead of time pays off tenfold."

Animation of molten lava, beer and milk also required special attention. For a scene in which Farquaad threatens a gingerbread man with death by dunking, effects animator Erdem Hamsi Taylan directed the flow of milk into a glass with a series of virtual jets inside the stream of liquid. "It's similar to what you might do on set for a commercial shoot," noted Bielenberg. "As the milk came down, we kicked on a jet at the right point to create an interesting splash up the opposite side of the glass. We also placed virtual obstacles in the path of the flow to direct it in a particular direction."

With the exception of one digitally composited live match flame and one live candle, all of the film's fire effects were also produced digitally by Bielenberg's team. The fire is seen most dramatically in Shrek's encounter with the dragon. "We'll use whatever works to create an effect," stated Bielenberg, "but the level of stylization and the interactivity of the dragon's fiery breath was almost like a character in itself, so we wanted the level of control we would have with CGI!" Digital fire was created with a series of volume rendering techniques- where light is rendered to pass through a pixel and refract within it, rather than bouncing off its surface- and a fireball simulation, devised by effects lead Arnauld Lamorlette, that utilized three-dimensional noise. "Arnauld used that three-dimensional noise to perturb the surface of the fireball and create all sorts of interesting patterns. We could art-direct it and go through a lot of simulations fairly quickly, which was important. If you use too complex a simulation and it takes a week to render, it'll take you forever to get what the director wants."

Effects animator Martin Usiak handled some of the more spectacular fire effects, seen as Shrek, Donkey and Fiona traverse a rope bridge, the dragon on their tail, filling the frame with fire. "Arnauld and Martin studied the way real fire develops and churns," related Bielenberg. "They figured out that, rather than flowing through space, these spheres of flame were born in place, then grew, then died. Once he worked out the simulation for each shot in Maya, Martin exported it to PDI format, and Arnauld applied a number of rendering passes. The first pass merged the spheres into interesting isosurfaces. The three-dimensional noise texture was then applied, giving it a cauliflower look. Arnauld wrote a shader to differentiate hotter and cooler areas, brighter at the edges and darker if surfaces were seen flat on. Then he created a volumetric pass as a surface render and another pass that was more gaseous. We composited those layers to get the final look, and added heat shimmer and smoke."

Lamorlette also served as effects lead on a complex visual effect at the climax of the film- where Shrek delivers Fiona to Farquaad's wedding altar, only to discover the princess' true nature when a cascading, swirling vortex of light transforms her into a green and portly lady ogre. "That immediately sent up red flags for me," commented Bielenberg, "because it was described in the script by two words that send fear into the hearts of most effects supervisors: 'ethereal' and 'magical.' Both terms are very difficult to translate into conceptual art because they are not solid, tangible things; so we spent a lot of time waving our arms around saying, 'It's kind of like this.' They wanted a misty, smoke-like effect, although it had to be unlike smoke. It had to take a very definite form and it wasn't supposed to be ominous; it had to look luminescent, light and happy." After nine months developing concepts and animation tests, Lamorlette arrived at an effect that featured luminous fingers of light-emitting particles that crept up and around Fiona, obscuring her as it buoyed her aloft and rotated her in the air. Animators modeled particle simulations in Maya and converted these to PDI rendering systems.

From the filmmakers' point of view, the success of Shrek was, in part, attributable to the unique advantages of the CG format. "The great thing about CG is that it is very iterative," stated Andrew Adamson. "If a scene was almost finished, and we felt it would help if a character looked down and blinked, showing he was being a little untruthful about what he was saying, we could do that without having to redraw the whole scene." The flexibility of the digital medium also allowed Adamson to incorporate contemporary pop culture references into the film- in some cases, up-to-the-minute pop culture references, such as in a scene in which Fiona dispatches a pesky pack of merry men in green tights. Originally storyboarded as an homage to Hong Kong fight master Jackie Chan, the scene was later informed by The Matrix frozen motion effects, and finally incorporated a nod to a more recent martial arts epic. "Two weeks before we finalized animation on the fight, Crouching Tiger, Hidden Dragon opened. One of our animators saw the film and suggested that Fiona could do a triple kick at the end of the scene, similar to one of the stunts in that picture. So we added that, as well as heightened impact noises and flapping cloth effects in the dub."



The perennial loner Shrek finds true romance when he discovers that the bewitched Fiona, in her true form, is actually a female ogre.



Surrounded by fairy tale creatures, now their friends, Shrek and Fiona board an enchanted carriage for a honeymoon getaway.

While enjoying the lack of physical restraints afforded them in a CG feature, the filmmakers still attempted to bring a live-action sensibility to the film. “If we were dolly-ing alongside the actors and they stopped,” stated Adamson, “I wanted the dolly to come to rest just behind them, as if the operator was allowing the camera to settle. The audience is never aware of this kind of visual language until it is not there. Being sensitive to that helped us trick viewers into believing the animation was alive. We also used slow-motion in the scene where the characters were escaping Fiona’s castle. You’re used to seeing that in a Jerry Bruckheimer film; so, again, it makes it seem more real, as well as funny.”



A rousing musical finale was produced after the movie’s theatrical release for incorporation into home video versions of the film.

The digital animation medium is still relatively new, and PDI/DreamWorks has only recently stepped up to the plate as a major force– yet, despite the embryonic nature of both the medium in general and this creative team in particular, Shrek reverberated with audiences for its unique style and voice. “I don’t think there is a PDI/DreamWorks house style yet,” Adamson observed, “at least not in the same way as there might be at Pixar, for example. But there was one overriding credo at PDI– which was that the story had to drive the technology, and not vice versa.”

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SLEIGHT OF HAND

image

ARTICLE BY Joe Fordham

The most magical aspect of J.K. Rowling's Harry Potter novels may have been the long lines of children snaking around bookstores prior to the midnight release of the the skinny, bespectacled, young wizard-in-training's latest adventure. Primed by three previous literary excursions into the fantastical world of Harold James Potter, each increasingly popular, the unveiling of Harry Potter and the Goblet of Fire, the middle volume in a projected series of seven, became an instant pop culture phenomenon. The seeds for Rowling's remarkable achievement- widely credited with having imbued videogame-era kids with a passion for the printed word- were sown in June 1997 when her literary debut, Harry Potter and the Philosopher's Stone, hit bookstores in Britain. Shortly thereafter, interest spread to the United States, where the retitled Harry Potter and the Sorcerer's Stone and its successors began to dominate the New York Times bestseller lists, eventually winning Harry a Time magazine cover and sparking sales of more than 100 million books, printed in forty-two languages from Albanian to Zulu.

Before Harry fever peaked, British producer David Heyman alerted Warner Brothers executives to the phenomenon occurring in the nonmagical 'Muggle' world. In late 1999, the studio announced its purchase of an option to film the first four Potter books, and screenwriter Steve Kloves was commissioned to adapt the initial installment. Harry's continued rise to fame- catalyzed by the popularity of Rowling's second and third novels, The Chamber of Secrets and The Prisoner of Azkaban- drew the attention of an eclectic roster of potential movie directors,



Millions of fans, young and old, eagerly awaited the film adaptation of Harry Potter and the Sorcerer's Stone, the first of author J.K. Rowling's phenomenally popular children's novels. Sought after by a number of A-list directors, the project finally went to Chris Columbus. On the set at Leavesden Studios in England, Columbus works on a scene with actors Daniel Radcliffe and Rupert Grint as young wizards-in-training Harry Potter and Ron Weasley.



Early on, the film introduces eleven-year-old Harry, an orphan enduring a drab and dreary existence in the home of his Uncle Vernon and Aunt Petunia Dursley (Richard Griffiths and Fiona Shaw). Unaware of his genealogy and wizard heritage, Harry is baffled by strange goings-on around him, such as flying letters from an unknown sender streaming into the Dursley house through the letterbox, doors and fireplace. Special effects supervisor John Richardson created the

including Terry Gilliam, Peter Weir and Steven Spielberg.

gag on set, firing thousands of envelopes from rotating wheel rigs. Strategically placed fans and air jets kept the ejected envelopes aloft.

By late March 2000, an official Warner press release revealed the appointment of Chris

Columbus as director of the film. Further media announcements assured Potter devotees that Rowling had given the production her blessing and was involved in casting and creative decisions; but with audience anticipation running high, Potter websites still fretted over what Hollywood would make of Harry's first year at Hogwarts School of Witchcraft and Wizardry.

To the relief of millions of readers, the film adaptation was remarkably faithful to the novel- in as far as a generous 143-minute running time would allow. Following the thread of Rowling's narrative, Harry Potter (Daniel Radcliffe) is introduced as an eleven-year-old living in a cupboard under the stairs at Four Privet Drive, Little Whinging, Surrey, the suburban English residence of his Uncle Vernon Dursley (Richard Griffiths) and Aunt Petunia (Fiona Shaw).

Ostracized for his peculiar propensity for creating inexplicable vanishings and levitations, Harry endures the disdain of his aunt and uncle and suffers the torments of his corpulent cousin, Dudley (Harry Melling)- until, one day, a letter arrives that changes his life. Harry learns that he is the orphaned son of two highly regarded wizards, and he is invited to enroll at Hogwarts great and ancient school of magic. Here, beyond the everyday Muggle world, Harry finds that he fits in. He makes new friends and adversaries, encounters menageries of mythological creatures, develops his wizard skills, and eventually learns the truth about his parents' deaths, linked to the possession of a mysterious Sorcerer's Stone.

Packed with eccentric humor, whimsical spectacle, magical events and colorful, fantastic characters, including trolls, goblins, giants and dragons, the production clearly required a sorcerer of its own to bring the story to the screen. In May 2000, visual effects supervisor Robert Legato- with credits such as Apollo 13 and the Oscar-winning Titanic to his name- stepped into the role of 'Über-visor,' overseeing the full array of visual effects required for the production, which at the time of his appointment was already taking shape in England. The weekend after completing supervisory duties on What Lies Beneath at Sony Pictures Imageworks, his current home base, Legato flew out to meet with production principals at Leavesden Studios in Hertfordshire, northwest of London. "They wanted to do everything that was in the first book," Legato recalled. "The hard part was determining what 'everything' was, and how much it was going to cost. We didn't have much time to make those decisions before shooting, so this became a financial challenge, designing effects that would be affordable, and without a lot of prep." Clearly, one of the biggest challenges facing production was an aerial championship game, played out on flying broomsticks, called Quidditch- a signature action sequence in both the book and the film. "We decided to put Quidditch on the back burner because it was a sequence unto itself, and we knew it would require a lot of research and development."

Rooting the production in England afforded the Harry Potter team access to fitting British locations, as well as tax relief offered by the British Film Commission to visiting foreign productions. But the incentives stipulated a distribution of labor between facilities on both sides of the Atlantic, which posed a logistical challenge to the visual effects effort in general, and, in

particular, to Rob Legato, who was unfamiliar with the current British effects scene. "Although I had worked in England before, on *Interview With the Vampire*," Legato stated, "I still had to go by the companies' latest show reels and reputations. I had to assess not only their creative abilities, but also their physical capabilities and, ultimately, their technical capacities based on their current work in-house. We had a 600-shot show in the beginning, and it was so CG-intensive, it seemed a bit too risky to plant a lot of the more CPU render-intensive creature work in London, especially with our short delivery schedule and their window of availability; so we knew we would be allotting much of that to Sony Imageworks and Industrial Light & Magic. But there were some pleasant surprises. Some of the London companies- The Moving Picture Company, in particular- came up with some fabulous animation for us, so we gave them more to do as we went along, which eased the load on the U.S. companies."

Prior to Legato's engagement, David Heyman and Chris Columbus had initiated concept tests for selected characters at Industrial Light & Magic and at Jim Henson's Creature Shop in London, with the two companies exploring CG and puppet techniques, respectively. As always, the filmmakers hoped to utilize as many practical effects as possible in the depiction of their fantasy characters. "Practical effects are easier to shoot," said Legato, "and they make it easier to conceptualize scenes. So we tried to use physical effects whenever we had the opportunity; but we knew we would have to glue together the balance of the effects with CG."

Ultimately, the film's visual effects embraced a broad range of techniques; but their designs were initiated at every point under the auspices of production designer Stuart Craig. "Stuart was a major artistic contributor to the film," remarked Legato. "I've always believed designs should come out of one person's head, because that one person can contain the vision of the whole project. I think Stuart was a little nervous at first that visual effects were going to take over an artistic portion of the film; but we assured him that was not the case, and he became very comfortable working with us." Craig's designs informed character creation, which involved the physical talents of makeup effects supervisor Nick Dudman and Jim Henson's Creature Shop, as well as digital character creation at ILM, Sony Imageworks, Rhythm & Hues, The Moving Picture Company and Mill Film. Craig's designs for the wizard and Muggle environments incorporated digital effects by Mill Film, Cinesite (Europe), The Moving Picture Company and Computer Film Company, combined with practical elements by miniature effects supervisor Robbie Scott, owner of Cutting Edge Effects in Borehamwood, England. For the production's centerpiece Quidditch match, Mill Film's motion control unit joined forces with mechanical effects supervisor John Richardson to realize elements for the sequence that erased the borders between live-action photography and Imageworks' virtual domain.

Orchestration of the gargantuan production was undertaken by visual effects producers Cari Thomas and Karen Murphy, who shared duties, the former overseeing the effort from Sony Imageworks during the final three months of postproduction in Los Angeles, the latter working from Leavesden. Legato also deputized two associate visual effects supervisors, Michael Kanfer and Nick Davis, to assist with the bicoastal operations. Davis, a British visual effects supervisor, assisted second-unit director Peter MacDonald, and served as Legato's eyes and ears in England. Kanfer, an American who shared Oscar honors for *Titanic* with Legato, ran technical quality control and, amongst other duties, set up custom satellite links via NeTune

Communications, bridging distances between Potter's eight visual effects facilities– five in London, three in California.

As preproduction proceeded, Mill Film installed a team of artists at Leavesden to begin previsualization with Legato. Situated adjacent to the art department, the animators translated production blueprints into 3D models in Softimage to establish the parameters for miniature, digital and physical effects. Concurrently, research and development began at Imageworks, under the guidance of visual effects supervisor Jim Berney and four lead CG supervisors– Peter Travers, Mark Lambert, David Smith and Seth Maury– who developed their own digital tools, while animation supervisor Eric Armstrong, CG setup lead Todd Pilger and CG modeling lead Kevin Hudson began initial character construction and controls development. In late November, Imageworks artists Pepé Valencia and Jason McDade joined the previz team in England, focusing on Quidditch. But prior to this, by late September 2000, cameras had already begun rolling at Leavesden and at mysterious locations, beyond prying Muggle eyes.



Harry again encounters the unexplainable during a family outing to London's Regents Park Zoo. There, a giant python slithers out of its enclosure– whose glass face magically dissolves– pausing to thank Harry for his help before escaping the confines of the reptile house. Jim Henson's Creature Shop provided an animatronic python for the scene, filmed at the real Regents Park Zoo.

Harry Potter and the Sorcerer's Stone begins, like the novel, on perfectly normal, dull-gray Privet Drive. Constructed on the backlot at Leavesden, the stretch of bland suburban homes was filmed at night and extended into an eighth-scale row of eighteen houses, built from scratch by Robbie Scott's miniature team. Mill Film motion control supervisor Malcolm Wool-dridge and director of miniature photography Nigel Stone shot the miniature against greenscreen on a Leavesden stage, with Mill Film visual effects supervisor Karl Mooney then blending that element to the full-scale set, adding digital mist and light effects to suggest lampposts being extinguished one by one. The eerie scene grows more surreal as a Triumph motorcycle bearing an enormous hirsute rider descends out of the night sky and touches down on the street. A stunt performer supervised by Gregg Powell rode the cycle flying rig, hung from an overhead crane by John Richardson's physical effects crew. The landing required minimal rig removal by Mill Film; then the action cut to actor Robbie Coltrane as the softhearted giant and Hogwarts gamekeeper Rubeus Hagrid.

Outside the Dursley home, Hagrid delivers a bundle containing infant Harry to wizard Albus Dumbledore (Richard Harris), the Hogwarts headmaster, who discusses the orphaned child's destiny with his robed associate Minerva McGonagall (Maggie Smith). Character makeup artist Amanda Knight designed the wizard makeups, which featured hair work by Zo' Tahir. "The whole point of the wizards in this film was that they were real," stated Nick Dudman. "We certainly came up with some lovely weirdo characters elsewhere in the movie, but Chris Columbus felt it was very important that nothing was caricatured in any way with our leading players."

The production adopted a similar low-key approach to Harry Potter's trademark distinguishing feature- a scar in the shape of a lightning bolt on the center of his forehead, evidence of his portentous past. "We had many discussions about how graphic to be with the scar," Dudman recalled. "In the end, we settled on a Dermaplast effect that Amanda applied." Dermaplast is a



Artist Chris Fitzgerald finalizes the paint job on the silicone snake, which featured an animatronic head and rod-puppeted body.



While the Henson snake sufficed for camera line-up and shots requiring limited movement, more animated and closeup views relied on a computer generated python crafted by Industrial Light & Magic.

common makeup product that can be painted on to simulate scar tissue. In some instances, the product– which, when dry, looks like flesh– is built up in layers as an alternative to prosthetics. “Our feeling was that we didn’t want to disfigure our main star with a gaping wound that would constantly draw your eye. It had to ‘read,’ of course, but there also had to be a degree of subtlety to it.”

Tilting down from a closeup shot of Dumbledore, the camera closes in on the tiny scar on the infant’s head, then magically enters it, rushing past storm clouds and lightning to reveal the movie’s main title, based on a visual treatment by Imaginary Forces in New York and executed by The Computer Film Company in London. 2D artist Jonathan Fawcner assembled the journey through the scar from a series of digital still photographs of a stormy evening sky taken from the CFC roof above Wells Street, overlooking London’s Soho. He took those images into Nothing Real’s Shake and created rolling cloud effects using Reelsmart’s Twixtor time compression program, darkening the sky to night and adding intermittent flashes in time to John Williams’ dramatic musical score. The 500-frame shot concludes on a white-out that fills frame and sends the viewer back in a reverse zoom from the scar to a now eleven-year-old Harry, sitting gloomily in the cupboard under the Dursley stairs.

Harry’s dark mood is eclipsed by Dudley Dursley’s birthday, as the chubby lad is showered with gifts and treated to an outing to Regents Park Zoo, in Central London. Harry is dragged along and stands in the reptile house, gazing sullenly into the glass cage of a sleepy Burmese python. Magically, the glass barrier melts before him, and the python bids Harry his thanks as he slips away, terrifying Muggles in his path. The scene was shot on location in the real Regents Park Zoo, where authorities permitted the production to construct a partial set on the historic premises, and make use of a Henson animatronic snake. Used for sleeping scenes and camera line-up, the silicone reptile was patterned after a live python and sculpted with intricate surface detail under the supervision of Henson creative director Jamie Courtier. On set, Guy Stevens operated the snake, which was essentially a rod puppet with an animatronic head.

For the shoot, John Richardson rigged the front face of the reptile’s habitat with a sheet of plexiglas, hinged at the top to give way as a performer leaned on the glass. ILM visual effects supervisor Roger Guyett and visual effects producer Denise Ream oversaw plate photography and reflection passes, then sent elements to sequence supervisor Kevin Reuter back at the ILM facility in San Rafael for the creation of digital effects and snake animation. 3D modelers Paul Giacoppo and Omz Velasco created a CG version of the Henson snake puppet. Susan Ross painted the digital model, again matching the practical snake, then Reuter applied surface shading and lighting that incorporated iridescence effects to simulate shimmering reptilian skin tones. Animator Paul Kavanaugh animated the reptile’s slithery departure, and lip-synced a sibilant ‘Thanksss’– voiced by Guyett. Compositing supervisor Marshall Krasser handled compositing issues on the sequence.

The calamitous birthday excursion further estranges Harry from his foster parents, as do the seemingly knowing creatures that begin to hover on the fringes of Uncle Vernon’s suburban existence. Animal trainer Gary Gero– who founded Birds and Animals Unlimited in 1964– provided, trained and supervised all of the live animal performers for the film, including dogs, cats, rats and horses. For the story’s ubiquitous owls, the production not only photographed

Gero's live birds on location, it also captured footage of the creatures on a bluescreen stage at Leavesden. Rhythm & Hues visual effects supervisor Richard Hollander traveled to England to work with Gero in filming the bluescreen owls. "We shot 93 takes of single owls in flight," Hollander recalled. "We had various sizes and several breeds- eagle, snowy, horned, gray and tawny- flying in front of a wind fan and landing on a bluescreen. Gary did a great job of getting them to fly. Despite popular belief about wise old owls, these birds were as dumb as chickens. The only way to make them fly was by baiting them with chicken parts. But once they were full, that was it- they stopped flying. There was nothing in their contract that said they had to fly anymore!"



Production visual effects supervisor Robert Legato confers with SonyPictures Imageworks visual effects supervisor Jim Berney. Both U.S. and British effects houses contributed to the picture.



Harry learns of his magical birthright from gentle giant Hagrid (Robbie Coltrane), who takes him to the wizard world's Diagon Alley to make a withdrawal from Gringotts Bank. The street set, built on stage by production designer Stuart Craig, consisted of only the ground floors of the bank and adjacent structures. An eighth-scale miniature, shot motion control and tracked to the set by Mill Film, provided the upper stories, with matte paintings extending into the distance.



The bank is staffed entirely by goblins, played by small performers fitted with makeups by creature effects supervisor Nick Dudman.

Early in the film, Harry peers out of a window and sees owls swarming around the Dursley home. Rhythm & Hues 2D supervisors Harry Lam and Kenneth Au sampled the bluescreen bird elements in *Inferno* to build a Hitchcockian array of some two hundred birds for the sequence. Later scenes employed wholly digital owls built by the Rhythm & Hues team, which drew reference from Hollander's bird photography and relied upon the company's expertise in character animation and fur rendering technology. "We produced two types of CG owl," digital effects supervisor Mark Rodahl explained. "We had one closeup high-resolution owl, but most of our scenes were wide shots using a low-resolution owl. These didn't need a tremendous amount of feather dynamics, so body feathers were modeled like feathery fur textures, mapped onto cards to cover the bird's skin. We modeled the main wing and tail feathers and set them up to move as they do in nature; so the CG birds could spread their wings, and feathers would fan automatically. We then did specific tweaks of feathers ruffling as secondary animation." The high-resolution owl- seen later in the film, taking flight from Harry's arm- employed greater detail around the bird's eyes and its face and legs, with feathers placed individually in the skin and combed back onto the bird's body. Craig Talmy supervised animation of all CG birds in Rhythm & Hues' proprietary Voodoo animation system, while Pauline Ts'o oversaw lighting and rendering in the company's proprietary Wren.

When Uncle Vernon discovers that the owls have gathered to deliver a letter to Harry from an unknown sender, he prevents Harry from receiving the envelope, and a flood of repeat deliveries pours through the door, filling the room with a cyclone of stationery. John Richardson realized the scene as an entirely practical effect. "The flying letters were a great example of the style of the film," observed Rob Legato. "We decided to do as much practically as we could; but since that



Eight hero goblins sported silicone prosthetics, while background characters wore pull-on masks.



After buying a wand and other magical necessities, Harry is presented with another accoutrement of the wizard lifestyle- an owl named Hedwig. Although a live owl was featured in the film, Jim Henson's Creature Shop built an animatronic one for non-flying closeups. Tahra Kharibian-Zafar works on the puppet Hedwig.

seemed a nearly impossible thing to do practically, we also budgeted for CG. In the end, though, we didn't need CG because the practical effect worked so well."

Richardson's team constructed eighteen letter ejectors that launched 100,000 envelopes from rotating wheel mechanisms, grabbing letters from a stack and flinging them out, rapid-fire, like an automatic tennis ball serving machine. "It took a lot of effort to create rigs that would fly the letters the distance we wanted," Richardson commented. "But once we had done that, it was just a question of positioning them in the right places. Stuart Craig designed the sets so we could introduce our letters through the chimney and through the letterbox, and then we had fans and air jets on the set to blow them around. We also built a system of grilles in the floor so we could take up panels of carpet and feed air from underneath to keep the letters floating longer in the air. We repositioned the ejectors for each setup and kept them going throughout every shot." Another rig could fire an envelope across the set and hit a specific target with extreme accuracy. "We could fire one twelve feet and hit an actor between the eyes. We made special rubber envelopes for that- and it was really Richard Griffiths on the receiving end when Uncle Vernon got one in the face."

Frazzled by the assault, Dursley transports his wife, child and Harry to the most isolated spot he can locate- a stone cabin perched on a rocky outcrop on a storm-tossed coast. The Moving Picture Company created a 3D hut for an establishing shot and tracked the digital structure into a daylit aerial plate, corrected to a classic dark and stormy night. "Chas Jarrett built the hut based upon art department conceptual art and photo-textures of Cotswold stone constructions," explained MPC producer Martin Hobbs. "We stitched together a new sky plate, and Julian Mann generated CG rain and CG spray coming off the waves as 3D particle animation. We gave the hut a wet and glistening texture and added a little gas lamp swinging violently in the wind. Greg Salter then put the shot together in Cineon."

To the Dursleys' dismay, another owl appears, accompanied by the enormous, hairy Hagrid, who smashes through the door and stands towering seven and a half feet above them. Hagrid closes the first act by disclosing to Harry that he is the famous orphaned son of James and Lily Potter. He then whisks the boy away to equip him with the accouterments befitting a young wizard, leading him to a dingy London pub, the Leaky Cauldron, and to a small, enclosed courtyard where he taps a combination of bricks in a seemingly solid wall. The bricks retract and rotate to reveal a doorway- an effect accomplished at Mill Film by mapping photographic textures onto animated 3D bricks- and the pair step through to Diagon Alley, a bustling crooked wizard high street, off limits to Muggles.

Filmed on a soundstage at Leavesden, Diagon Alley was realized as a full-size set, backed by greenscreen for the compositing of digital matte paintings by Mill Film and a miniature set extension of one of the principal buildings, Gringotts Bank, constructed by Robbie Scott. "There wasn't enough height within the soundstage to reproduce the top of Gringotts Bank," said Scott. "The front of the bank had pillars at weird angles, with buttresses and supporting timbers holding it up on one side. It would have been very tall to produce as a full-sized set, so they decided to make it a model. We added two floors and walls that came off from each side with an eighth-scale miniature."

Mill Film shot the Gringotts Bank miniature motion control, utilizing data tracked from the live-action plate and the same wide-angle lens. "It took a good month to compensate for the lens distortion and get that shot together," commented Karl Mooney. "Once we blended the two elements, we photographed sky plates, added live-action bluescreen people, steam and a 2D/3D matte painting of buildings to extend the alleyway into the distance. We also incorporated foreground elements, such as extra signage and a building framing the higgledy-piggledy front of Gringotts."

Hagrid and Harry enter the bank to withdraw a sum of wizard currency from a Potter trust fund. Once inside, they encounter a stately counting house run entirely by goblins. Photographed for three days on location in the Exhibition Hall of Australia House on London's The Strand, the scene featured goblin characters portrayed by fifty small performers fitted with prosthetic makeups- though production originally had explored a digital approach. "Early on, while I was still completing *The Mummy Returns*," recalled Nick Dudman, "we went to a theater in London and they screened a twenty-second test that ILM had done for a CG goblin. It was absolutely stunning- a beautiful, bulky little chap- but the producers asked me if I could come up with something as good. I blithely said, 'Yes.' A lot of people at that time had been doing gorgeous work with silicone makeup. I'd done a little on *The Mummy Returns* and *The Phantom Menace*, but I'd never thrown myself into it because the technology was new, expensive and quite labor-intensive. I was waiting for something that would justify going to that extreme- and this was it. I thought it would be a heck of an achievement to do the Gringotts goblins completely in silicone."

Working from renderings by art department conceptual designers Robert Bliss and Paul Catling, Dudman artists Paul Spateri and Mark Tulliet oversaw production of goblin designs as clay maquettes. After creating proof-of-concept test makeups with Warwick Davis as a goblin bank teller, Dudman artists then generated eight hero characters using silicone gel prosthetics, allocating the remainder as silicone pull-on masks. Hero makeups broke down into four sections: a single appliance covered the back of the actor's head and sprouted pointy goblin ears; a forehead piece joined with this, blended into the top of the actor's head; a central facial appliance then incorporated nose, upper lip and cheeks, extending to the ears; and a lower lip and chin piece completed the coverage. Laboratory lead Andrew Lee formed bulkier appliances over foam latex cores, which helped reduce the weight of the prosthetic on the actors' heads. Three makeup artists applied each hero makeup, utilizing Premiere Products Telesis Four as an alternative to the industry-standard 355 medical adhesive. "Silicone doesn't stick quite the same way as foam, and it can be quite tricky," Dudman commented. "But we found that Telesis Four worked very well." Dudman's team painted fleshy color schemes on the characters' skins, and darkened their eyes. "I suggested all-black eyes because it was creepy looking; but it also meant that we could generate all of our background masks with empty eyeholes, and from a distance they would look the same as the closeup characters. This meant we didn't have eyes steaming up and actors sweating too much because they couldn't breathe inside the masks." Goblin performers, who averaged between three and a half and four feet tall, also sported prosthetic finger extensions and had costumes designed to give them elongated feet.

The goblin Griphook (Verne Troyer) admits Hagrid and Harry to a vault containing the Potter family fortune, and to a second mystery vault secured by a convoluted security system devised by the special effects crew. “The vault door was covered in locks and links and gizmos,” said John Richardson. “My mechanical designer, Bob Bullimore, built a mosaic of Victorian levers and linkages that moved together and rotated in a very intricate way. It was an amazing mechanism.”

Richardson also constructed a mine car for part of the Gringotts sequence, ultimately dropped, in which Hagrid, Harry and Griphook are transported to the Potter vault via a wild, subterranean roller coaster ride. Rob Legato previsualized the scene as an ambitious, single, fluid shot, but the journey was excised to compress the narrative of the novel. “The way it was devised,” explained Legato, “the camera started behind the mine car going through a tunnel, we circled around the car, passing between pillars, then came out in a cavern with stalagmites and stalactites and a lake below. Once we came up with the basic template for the shot, we were going to convert motion control data to the practical cart, then tie it together as a handoff from the real cart to a CG cart. It was a good example of the seamless style of shots in the film.”

Armed with wizard currency, Hagrid takes Harry to Ollivander’s Wand Emporium, where Ollivander (John Hurt) furnishes Harry with a maple-and-phoenix-feather wand. Moving Picture Company, Cinesite and Smoke & Mirrors generated sparkling wand effects seen throughout the production, with the major-ity of them falling to MPC. “Each wand, each person and each spell had its own signature,” commented Legato. “We wanted a logical reason why each wand effect looked the way it did, and we didn’t want a big light show because we’ve all seen that before and know instantly that it’s an effect.” Legato encouraged wand effect providers to experiment with their own designs to capture the feeling



First-year students, Harry among them, arrive for the new term at Hogwarts School of Witchcraft and Wizardry. The nighttime approach was a multilayered composite assembled by Mill Film. In addition to matte-painted backgrounds and live water-tank elements, the shot was comprised of two Hogwarts miniatures– a castle and its surrounding landscape, built at different scales and shot separately. For nocturnal views, modelmakers rigged the structure with fiber optic points of light to simulate the glow of flaming torches. Additional CG water elements and reflections from the boat lanterns sweetened the shot.



Arriving students enter the Great Hall, where candles float in midair and a transparent ceiling provides a view of the night sky. Floating candles in some shots were achieved by the physical effects crew, which hung flaming nylon cylinders by tungsten wires from gimbals. Other shots featured CG candles. The magical ceiling was a night-sky matte painting projected onto a 3D re-creation of the practical set by Mill Film.

of Rowling's colorful prose. "Our 2D team loved that," remarked MPC head of production Michael Elson. "Greg Salter really went to town, creating mixtures of particle animation and 2D light effects. We like to experiment with producing 3D effects using 2D tools. There's no point in using 3D if you can produce effects in a more timely manner and get the same result, or better."

Outfitted with wand and wizardry supplies, Harry accepts a gift from Hagrid of his wizard's 'familiar,' a beautiful snowy owl named Hedwig. A featured character in both Rowling's novels and the film, Hedwig was portrayed by a seasoned sixteen-year-old male snowy named 'Ook,' who performed many of his own stunts, both aerial and perched. But as an insurance policy, Hensons also produced an animatronic double of the perched bird. Sculpted by Chris Fitzgerald and feathered by Tacy Kneale, using mostly goose feathers obtained from the food production industry, the Henson Hedwig was mechanized by Adrian Parish. "We built our Hedwig on a parallelogram mechanism that allowed her to shift her weight on her perch," explained Jamie Courtier. "She could blink her eyes, rotate her head 360 degrees- and that's about all owls do. She was only meant to be seen inside her cage, so we built all the mechanics inside the bird, with wires inside the perch that led down to the base where we hid our battery compartment, switch and receiver for the radio control. Guy Stevens operated her from off-camera, making her sway and react to her environment." Later, the animatronic was amended so that it also could be operated while perched on an actor's arm.

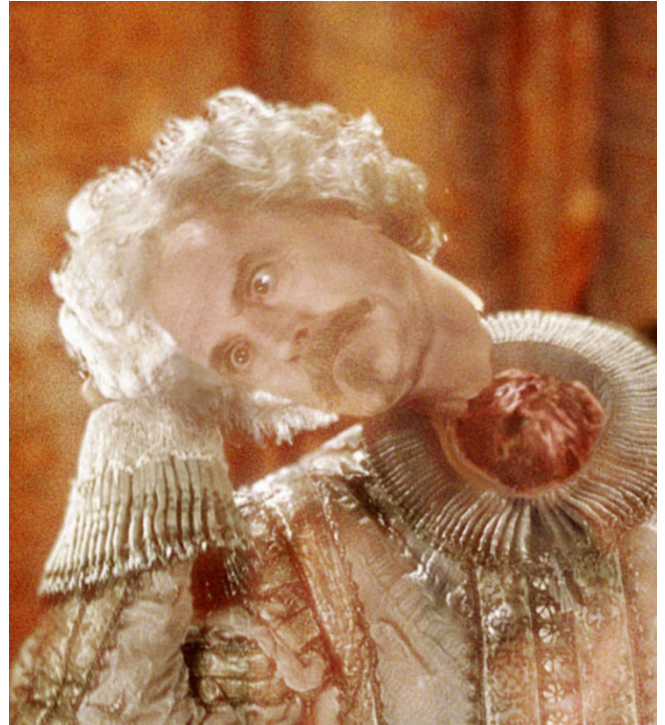


Harry submits to the school Sorting Hat, placed upon the heads of new students as a means of assigning house affiliations. On set, actors wore a wire-frame hat, later replaced with a computer generated talking version created by Rhythm & Hues. Since the practical wire-frame hat cast no shadows on the actors, R&H had to produce them digitally and composite them over the live-action.

The animatronic bird appears briefly in a sequence following Harry's shopping spree in Diagon Alley, as Hagrid drops Harry and his luggage at Kings Cross Station, leaving him to find his train to Hogwarts- departing the apparently nonexistent Platform 9 3/4; We had to film at Kings Cross," explained Rob Legato, "because it was so specifically laid out in the book. It was so cold and miserable there, and, I must say, relatively unattractive- but right in the middle of this very modern place, a very magic place existed. If you knew where to look, where to put your eye, you might catch it; but if you didn't, it was business as usual. That was how it was in the book, and we tried to be faithful to that idea. And that was why we planned Harry's entry to Platform 9 3/4 as one shot- it was sleight of hand."

Standing before the gates to Platforms 9 and 10, Harry spots another Hogwarts student, Fred Weasley (James Phelps), charging at the dividing wall, then, momentarily obscured by passersby, vanishing. Encouraged by Mrs. Weasley (Julie Walters), Harry steels himself to try the same approach. In an unbroken Steadicam move, the camera circles the boy, glimpsing the brick wall ahead, then continues trucking backwards with Harry and his luggage trolley as he charges. With a magical shimmer, the boy and camera pass through the wall emerging on the other side, the camera panning to reveal- without a cut- wizard students everywhere preparing to board the Hogwarts Express, powered by a gleaming red steam locomotive.

Legato previsualized the complex, uninterrupted move, plotting it with Chris Columbus and Stuart Craig, then shot the scene live, on location, with only minimal camera trickery. Craig's team had procured a sixty-four-year-old steam locomotive, the Great Western Railway Olton Hall, from the Swindon Steam Railway Museum, and dressed the engine and its tender with new nameplates and a coat of scarlet paint. They parked the train and its carriages at a platform in Kings Cross, then inserted a dummy section of brick wall at



A resident ghost named Nearly Headless Nick joins the festivities in the Great Hall. A live performance by John Cleese, in a variety of effects rigs, was manipulated by ILM to create the illusion of Nick's head unhinging from his body. Cleese was filmed wearing a black collar around his neck to simplify digital head separations. A CG neck stump bridged separately photographed head and body elements.



After the Sorting Hat ceremony, students enjoy a lavish feast, crashed by more flying ghosts. Live actors filmed bluescreen provided elements for five closeup characters, while background apparitions were entirely computer generated. A sophisticated compositing treatment enabled effects artists at ILM to desaturate the bluescreen elements and vary the level of transparency over different parts of the ghost bodies.

the platform entry. Legato staged a camera move to track around Daniel Radcliffe, establishing the dummy wall and modern commuter trains at surrounding platforms. When the camera reached its reverse position facing Harry, stagehands pulled the dummy wall away in time for Radcliffe and the camera to rush through. "By the time you understand what's happened," Legato related, "we've come out the other side. We couldn't slide the fake wall section back in place in time when we emerged on the other side, so we had a porter carry a bag across frame behind Harry at the moment he broke through. Later, we rotoscoped around the porter and Harry, so that when you see the wall back there again you don't know exactly when it reappeared. Then the camera pans, and you see the real train."

John Lockwood, a 2D supervisor at Cinesite in London, oversaw the tracking, rotoscoping, digital animation and compos-iting on the shot. Cinesite artists digitally removed the Olton Hall from the forward angle at the start of the move, tracking in smoke and an empty platform. For Harry's passage through the wall, Lockwood's team generated a 3D structure to represent the interior of the brick, using the geometry to impart a refractive quality to the background rotoscoped around the boy. "It was roto-intensive," stated Lockwood, "but it wasn't an overly technical approach. It was more a creative mixture of 2D and 3D to create a look, like being underwater looking out. We were creating the difference between these two worlds."

Harry makes his way towards the train, giving wide berth to fellow student Lee Jordan (Luke Youngblood), who is carrying his own pet in a box- a giant tarantula with a ten-inch leg-span, built by Nick Dudman mechanic Tamzine Hanks. Hanks modeled the radio-controlled arachnid after her own pet tarantula, Lilith, and mechanized its leg movement to allow hairy legs to poke out of Jordan's carrying case. Esteban Mendoza applied overall body fur to the puppet by flocking, then hair artists hand-punched hairs into detailed areas.

Soon after boarding the Hogwarts Express, Harry makes the acquaintance of fellow 'first-years' Ron Weasley (Rupert Grint) and Hermione Granger (Emma Watson). Actors played the six-minute scene against bluescreen at Leavesden, which avoided a complicated train location shoot, but necessitated seventy window composites with interactive lighting effects supervised by Rob Duncan at CFC. Early in production, second unit filmed locked-off lateral traveling views along the North Yorkshire Moors Railway. Working from a cut sequence of foreground and background elements, Duncan analyzed relative focal depths and exposures. Jonathan Fawcner then took the elements into Inferno and warped backgrounds to match foreground angles, which cut back and forth with actors. For shots at extreme angles to the window, Fawcner separated levels of scenery into mountains, trees and railway embankments, warping each at different degrees to create the illusion of parallax, trees slipping by faster than sky. Fawcner also added momentary flashes of light and dark to simulate passing trees, sometimes taking cues from lighting effects in cinematographer John Seale's foreground photography, sometimes animating passing shadows as dictated by the background plate.

During the journey, Ron introduces Harry to his rat companion, Scabbers, one of the animals provided to the production by Gary Gero. The Henson team created both a floppy puppet replica of Scabbers for handling during pocket insertions and retractions, and an animatronic one for more dynamic action. Sculpted by Chris Fitzgerald, fabricated by Tahra Kharibian-Zafar and dressed with hair by Tacy Kneale, the floppy Henson rat was built as a series of gel-filled

urethane sacks, which gave the creature a realistic softness in performers' hands. To add a little more life, Dan Burnett rigged a shuttle mechanism inside the puppet's nose. "We punched whiskers into it," said Jamie Courtier, "so that when the shuttle moved back and forth, his whiskers would vibrate." The animatronic rodent was operated on set by Guy Stevens.

Sharing wizard candy with his new friends, Harry discovers an enticing confection known as Chocolate Frogs- a small chocolate amphibian which, when unwrapped, leaps onto the window, then jumps out of the train. MPC modeled the Chocolate Frog in 3D, basing it on an art department maquette. "CG supervisor and lead animator Chas Jarrett nailed it in two takes," said Michael Elson. "We then created various swatches of chocolate texture, and ended up using one based on a chocolate Easter rabbit, which was very smooth with a slight sheen. We did have to sample a fair bit of chocolate in the process, which was tough, but we managed to get through it!"

Included with the Chocolate Frog is a wizard trading card featuring a curious three-dimensionality- a holograph-style image of Albus Dumbledore. On the set, Legato photographed Daniel Radcliffe holding a trading card with a bluescreen patch on it, then provided animator Jon Neill at Cinesite with a 3D scan of Richard Harris as Dumbledore. Composer Mark Michaels extracted highlights from the bluescreen patch and tracked them as a texture map over the scan, creating a surface sheen in perspective. He then composited that image back onto the bluescreen card, producing a fleeting illusion of depth as Radcliffe tilted the card.

After the Hogwarts Express pulls in to Hogsmeade Station- filmed on location at Goathland Station in the North Yorkshire Moors- Hagrid leads the students to a moonlit lake, where they cross in small boats towards Hogwarts, a grand and gothic old castle sprawled across a rocky outcrop. Production realized the castle as an amalgam of real-life locales, stage sets, miniatures and matte paintings. Hogwarts locations included Gloucester Cathedral, Durham Cathedral and Alnwick Castle in England, as well as the Scottish Highlands of Glen Nevis, where Braveheart had been filmed. Real-life settings informed the design of a preproduction foamcore mockup, which allowed Craig, Columbus and Legato to reposition the architecture until they arrived at a workable facsimile of their imaginary structure. Robbie Scott and a team of eighty-six modelmakers then translated the mockup into a camera-ready miniature in twelve weeks.

To maximize available space at Leavesden, Legato and Scott elected to build the Hogwarts miniature in two parts- a 1/24-scale castle and 1/96-scale landscape- built adjacent to each other on one stage. "The surrounding landscape that the castle sits in was based on the location in Glen Nevis," Scott stated. "Rob trimmed that to suit everybody's needs and added a lake. We added the boathouse, where the boats first enter, which is a little different from the book. We incorporated a courtyard with a tower and surrounding walls that were shot at Alnwick Castle, and we built two twin towers that were quite prominent at Durham Cathedral, although we capped them off with domed, conical roofs. We also fashioned a recognizable tower that housed an enormous marble staircase, and another structure that contained the Great Hall, which is the central meeting place at Hogwarts. Our model tied it all together."

The castle understructure was made from wood. Stonework, tiling, windows, doors, gargoyles and castellations were hand-sculpted by modelmakers, then molded and mass-produced in

resin, with textures trimmed and affixed to the understructure via contact adhesive and superglue. Modelmakers cast textures in glass-reinforced gypsum, which allowed castings to be bent and fitted to curved forms before they cured. Custom detailing included a miniature suspension bridge, fashioned from metal wire and layered with tiny strips of wood, metal railings and a weather vane that artists generated as 2D artwork, then acid-etched in thin sheets of brass.

The modelmakers carved landscapes from polystyrene, then laminated rocky outcroppings with plaster molded from slabs of coal, which created realistic scale cliff faces. David Westcott led an art department painting team to average out the mini-ature in tones that matched full-scale locations. Modelmakers then dressed the set- applying various grades of gravel to produce smaller rocks and falls of shale in mountain gullies- and utilized real vegetation for grass and miniature flora. "We used a lot of tree roots," Scott said. "It might sound funny, but if you clean and dry the capillaries on the root systems of small trees and bushes they lend themselves very well to creating trees in scale. By adding wire wool and flocking to that, we built them up into these very fine-looking trees. We also sometimes used roots for ivy creepers growing up over the castle; other times we mixed up very fine resin, pumped it out of a syringe, then applied a little flocking to give it some life."

The completed castle miniature stood twenty-seven feet tall, occupying an area of fifty-by-sixty-feet. Surrounded by greenscreen, the model was lit by Nigel Stone to simulate day, dusk and night shots. For nocturnal scenes, the modelmakers rigged castle walls with some 300 fiber optic points of light to simulate the glow of flaming torches and flambeaus. Stone fed the fiber optic cables with light sources controlling color, intensity and speed of flicker. To add atmospheric depth to the model photography, the production sealed the drafty stage and filled the set with smoke. Mike Kanfer then shot digital test footage and provided rough composites to help establish intensities of light needed in the multiple passes before Stone and Malcolm Wooldridge commenced filming.

The Hogwarts approach, a trademark shot for the movie and a teaser poster image, was subject to a great deal of analytical detail. The shot began with a live-action tank plate of Hagrid and the students in boats, sailing away from camera. The boats were surrounded by greenscreen in a ten-meter radius of water and towed from below. Using an on-set camera tracking system with overhead Scotchlite markers and infrared motion capture reflectors, MPC technical director Peter Muyzers interlocked the Super Technocrane move with a Maya digital model of the Hogwarts miniature. The tracking technology, originally developed by the British Broadcasting Corporation and Radamec Broadcast Systems for creating virtual sets in television, was adapted to introduce 3D animation to camera playback at film resolution by MPC, in exclusive partnership with the BBC and Panavision. Used for the first time in Europe on Harry Potter, the new system allowed Nigel Stone to frame shots accommodating the spires and towers of Hogwarts on the greenscreen set. Malcolm Wooldridge and his motion control team simultaneously encoded the camera move using a control system, devised by Chris Shaw, that applied data from the camera move to a re-creation of the crane in 3D space. Digna Nigoumi then converted the encoded data to the Mill Film Milo motion control rig, and Wooldridge and Stone shot five repeat passes of the miniature using an extended boom arm. Karl Mooney and

the Mill Film Soho team then united key light, atmospheric and flambeau passes with hundreds of interactive elements.

“We tracked the shot entirely by hand,” said Mooney. “David Early produced a digital matte painting of the moon and night sky. Nicki Wakefield added moving clouds in Nothing Real’s Shake, creating a multiplaning effect through layers of landscape, sky and stars. Once we combined the model elements and the greenscreen tank shots, Ian Plumb rotoed all the boats and did a soft blend in Inferno, mixing all the lovely orange highlights from reflections of the lanterns in each boat and the white reflections of moonbeams on the water. We used Areté to create CG water. Imageworks was kind enough to share some of the water technology they had developed for earlier projects, which we were able to adapt to our needs. Ian comped in some additional boats shot greenscreen, dry-for-wet, to help with the composition. We tracked in live-action flames to all of the flambeaus on the model, dressed it with mist, and combined everything in one huge move that started out looking down on the boats, then tilted up to see Hogwarts for the first time, with all its glittering lights.”

Professor McGonagall, the deputy headmistress, meets the new students and leads them into the Great Hall, a vast vaulted chamber illuminated by 350 candles, floating in midair. Surprisingly, all the levitating candles in shots of the children first entering the hall were real. “Each candle was made of a hollow nylon cylinder with a wick inside and a little spirit oil reservoir,” explained John Richardson, “so they wouldn’t burn down or drip wax. We hung those by tungsten wires from thirty-five overhead gimbals, each supporting ten candles on a frame. Chris Columbus wanted the candles to float, rather than hang there rock solid, so we connected each of the gimbals to variable speed motors, which made the frames tilt and bank at random.” Mill Film also generated digital versions of the candles for other shots; and, for a later scene during a Halloween celebration,



After the ceremony in the Great Hall, students descend Hogwarts’ marble staircase, which magically detaches and shifts in midair. For the live-action shoot, John Richardson built a full-scale staircase section capable of swinging in a 90-degree arc. For wider shots, bluescreen elements of the students were composited into a 3D staircase created by Mill Film, which based its CG construct on an eighth-scale miniature. As a finishing touch, Cinesite animated portraits hanging on the walls, compositing live performers into the frames and texturing the images to look like old oil paintings.

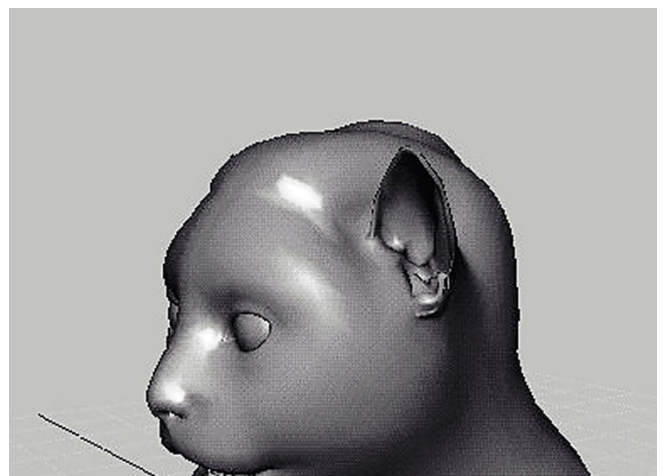
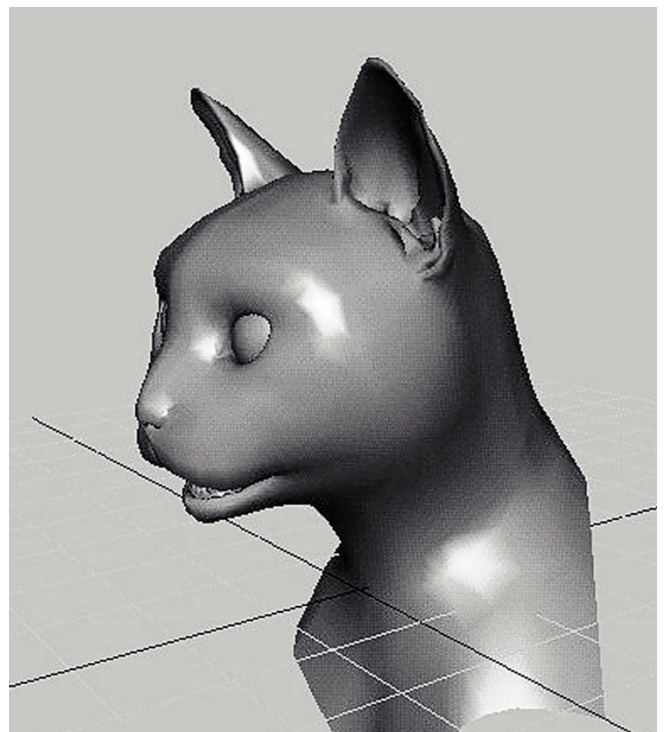
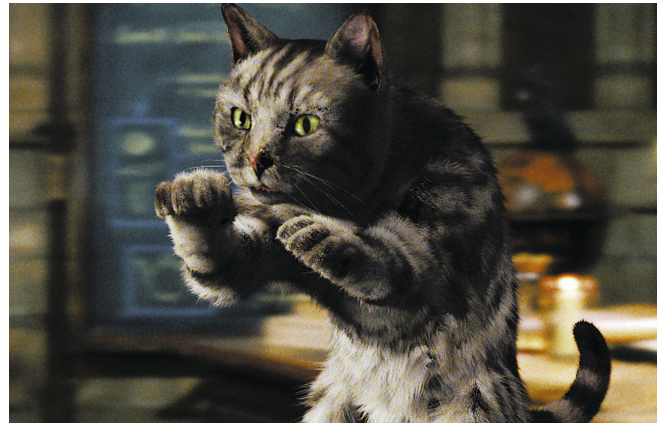


The Hogwarts curriculum includes levitation classes with Professor Flitwick (Warwick Davis). Hermione Granger (Emma Watson) shows up her classmates when her feather rises into the air— a practical effect rigged on the set.

the company digitally generated five rotating jack-o'-lanterns floating above the students' heads, glowing internally with flickering candlelight.

As students take their seats in the Great Hall, Harry gazes up at the ceiling and observes a peculiar optical illusion- stars in the night sky visible through the architecture above him. Rob Legato, Mill Film and Robbie Scott's team created the magical trompe l'oeil effect for two scenes in the film as a combination of live-action, digital animation and miniature effects. Working from art department plans, Scott engaged a computer numeric control machine shop to mass-produce Great Hall ceiling rafters from high-grade plywood. Modelmakers then assembled the eighth-scale structure, staining and finishing the wood to make it resemble aged oak timbers. The Mill Film motion control team photographed the miniature based on the camera moves established on the live-action set. To allow Chris Columbus unrestricted camera movement during the first-unit shoot, Malcolm Wooldridge employed Mill Film's custom encoder rig, facilitating repeat moves with a Panavision Millennium on an adapted Arri mount.

Placement of strategic tracking markers and a Lidar scan of the setting- by light detection and ranging specialists Air View Systems- then enabled the Mill Film team to blend digital animation with the live-action and miniature ceiling set. "David Early painted a giant 12K matte painting of the night sky for the magic ceiling shots," noted Karl Mooney. "Andy Kind projected this painting onto a 3D re-creation of the ceiling, and compositing supervisor Peter Jopling played some visual tricks with the reveal. When we first cut to the shot, we made sure that no set was visible, so we appeared to be looking up at sky; and then slowly, as the camera moved, we revealed unlit textures and roof geometry. As the viewpoint changed, we introduced shadow and highlights and created a separate layer of global illumination to break up the digital edges of the models. Gradually it became more solid as we dissolved into the miniature timbers and



eventually the full-size set. We also juxtaposed the interior and 'exterior' lighting throughout, so at first you see the moonlight coming in from the sky; then, as the camera descended, we mixed in the candlelight and flambeaus that lit the interior set, to visually confuse the eye." Mill Film completed the scene with a matte painting that extended the top of the far wall of the hall with a digital stained glass window, lit to correspond with interactive light effects.

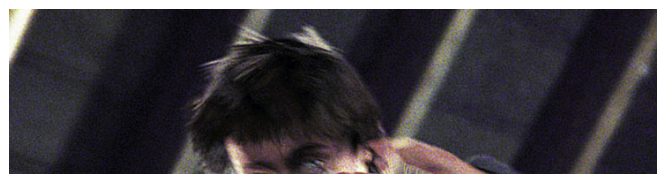
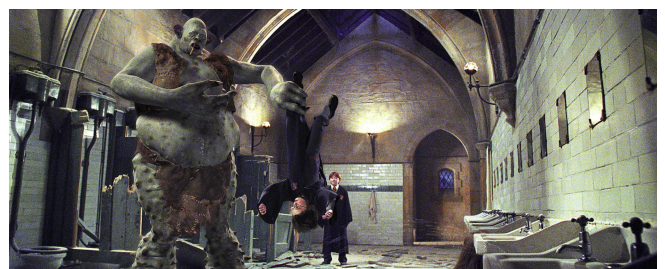
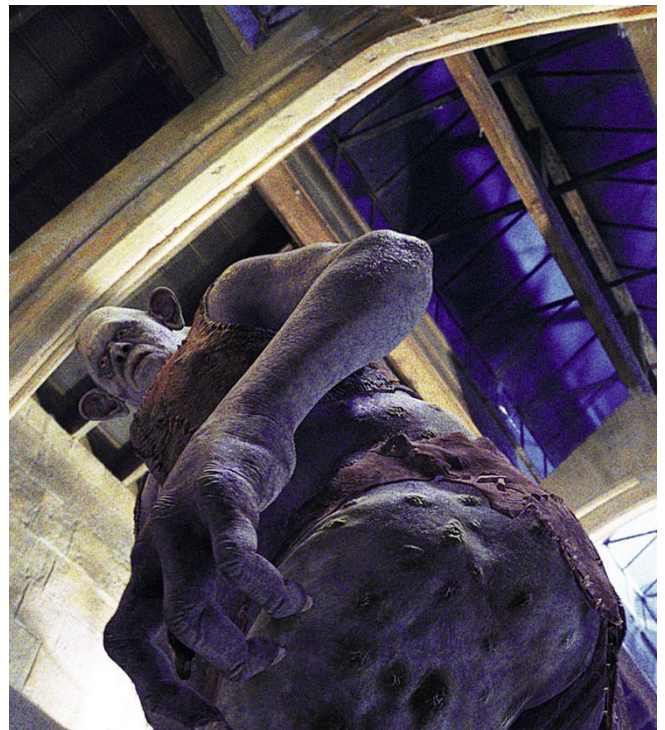
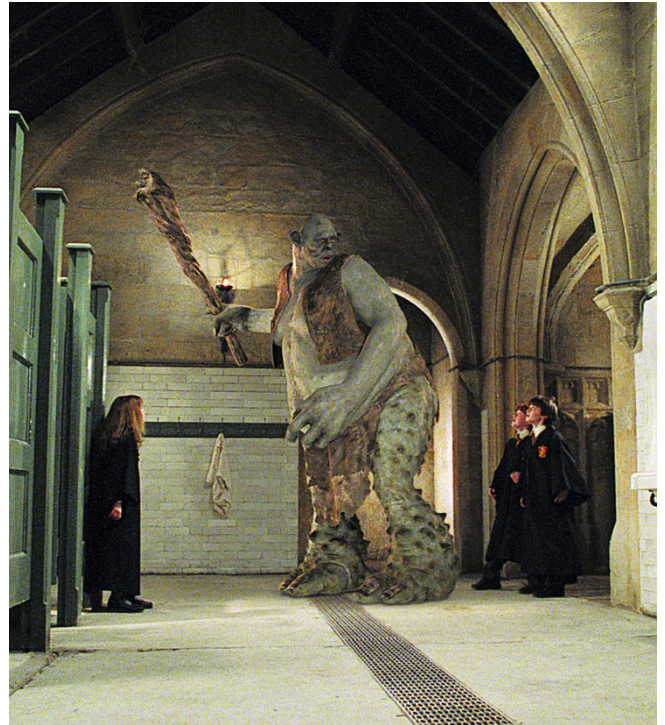
Seated among the Hogwarts congregation, Harry watches as McGonagall places a crumpled, round-brimmed wizard's hat- called the Sorting Hat- on a stool. The hat twitches and comes to life, its leathery textures taking on the appearance of a wrinkled face, then begins to speak, dictating house assignments when placed on each new arrival's head. On-set element supervisor David Takamura constructed a physical wire-frame tracking marker hat for performers to wear on set, then Rob Legato engaged Rhythm & Hues to create a digital version of the chatty headgear. "The Sorting Hat was a simple idea," said Legato, "so we didn't want to make it overly fanciful."

Nervous students prepare for their first flying lesson. Shots of Neville Longbottom (Matthew Lewis) rising into the air on his broomstick combined location elements with bluescreen stage work. In both cases, the physical effects crew mounted bicycle seats to a dozen variously configured pole-arms as a means of capturing 'flying' footage with live performers. The pole-arm rigs could be controlled in real time, with joystick mechanisms, or via motion control to ensure moves exactly duplicating those worked out in a previz animatic. Imageworks also created a digital Neville and broomstick for more dynamic shots of the hapless student flying skyward, bouncing along the castle walls and barnstorming his classmates below. / Arriving late for a class taught by Professor McGonagall (Maggie Smith), Harry and Ron find stationed at her desk a cat- which suddenly leaps and makes a midair transformation back into the professor. Rhythm & Hues realized the brief shot, morphing from a CG cat to an interim half-cat/half-human model, and finally to a CG likeness of Maggie Smith that was lined up to live-action photography of the actress.

Richard Hollander took delivery of the stand-in Sorting Hat at Rhythm & Hues. The prop was cyberscanned, and Hollander shot digital pictures of it to be utilized as textures for the 3D model. But the assignment was complicated by the fact that the prop hat R&H was using as the basis for the 3D hat was less crumpled than it had been on set, due to the change in climate from England to Southern California; so the geometry had to be built twice before animation could begin. "The major task for us was defining the character of this hat," Hollander recalled. "It already had a lot of folds in it, so I set out with the intent to work with those shapes and animate what was there, while trying to keep it feeling leathery all the way through. New folds might appear when it became a character, but they went away when it reverted to the real hat."

Hollander and Mark Rodahl chose a hybrid morphing/muscle technology to apply life to the hat that was in cadence with the pre-recorded voice. Craig Talmy's animation team and Pauline T'so's lighting department worked in tandem to accentuate expressive 'brow' folds, to indicate a 'nose,' create the semblance of 'lips' above the brim and add detail such as creases beneath the 'eyes.' Harry Lam's 2D artists then integrated the animated hat into the live-action and removed the tracking references. "The wire-frame hat itself never cast a shadow as it was placed on top of the wearer's head," Hollander observed, "so we had to create a CG head to cast our own shadows on as the hat came down, removing existing highlights, then having the shadow of the hat descend over the line of the wearer's nose."

During the Sorting Hat ceremony, Harry observes some residents and tutors from beyond the mortal realm joining the faculty. The novel's large specter population was confined in the film to a group of five closeup characters- photographed with live actors in England- and eight entirely digital background spooks summoned up by ILM. Ghost

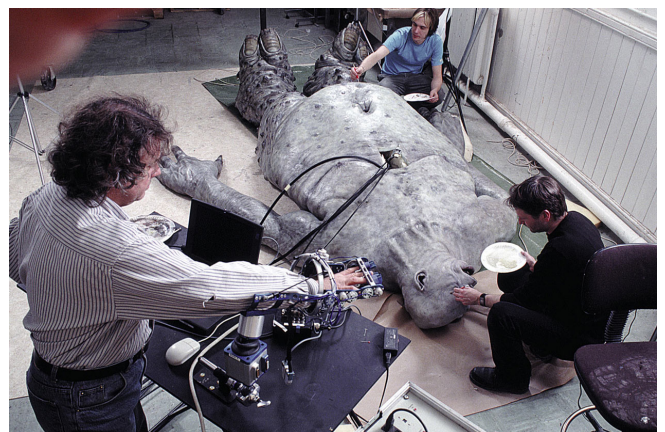


background plates were filmed at Leavesden, in the Great Hall set; but prior to that, ILM and members of the Mill had collaborated on an animatic to work out all the ghost action. Animator Dave Andrews then key-frame-animated the ghosts at ILM, working with Kevin Reuter and Aaron Pfau in the creature department.

Development of the look of the ghosts was led by Marshall Krasser in compositing, building from a concept that Rob Legato had envisioned. "The ghosts were very desaturated," stated Roger Guyett, "but with definition in their faces. A complex compositing treatment enabled us to vary the level of transparency over different parts of their bodies and give us total control of the look. Makeup and wardrobe helped us with the color palette for our ghostly performers, then Rob Legato and I shot a series of tests to come up with the lighting. We ended up having them backlit against black, two stops overexposed, with a front key-light one stop overexposed. That ratio between backlight and front fill gave us our basic ghost look."

Of all the specters, Sir Nicholas de Mimsy-Porpington (John Cleese) would prove the greatest challenge to Legato and ILM. Known to Hogwarts students as Nearly Headless Nick, due to a propensity for unhinging his semi-severed head, the character posed the problem of realistically combining Cleese's performance with the ghoulish mechanics of his head and neck. "We had endless discussions about how graphic to be with Nearly Headless Nick," commented Legato. "We didn't want to be too medically correct, with skin and bones and blood; we wanted it to be more nebulous. The feeling was that the idea should be more gross than the visual." Previsualization proved key to not only working out the aesthetics of the effect but the mechanics. "In our previz, we computer animated Nearly Headless Nick- had him reach up and flip back his head, then had it bob around. We worked out that if we shot our actor twice- once for his body, once for his head- and moved the camera to simulate the movements of the head, we could make his head appear to

On the night of Hogwarts' Halloween celebration, a giant troll invades the castle, cornering Hermione in the school lavatory. / The beast was computer animated by Imageworks and composited into a set built at Leavesden. Since the scene took place on a stormy night, Imageworks triggered lightning pots and shot separate plates of each flash. Those plates were then tiled to create a single high-illumination background, employed in the composite when lightning needed to flash. / When Harry and Ron come to Hermione's rescue, the creature grabs Harry and dangles him upside-down by his ankle. Rather than lining up live-action to the digital troll, Imageworks created a CG Harry for the shot. / The digital Harry was used again for a series of shots in which he leaps onto the troll's back and thrusts his wand up its nose. / Knocked unconscious by his own cudgel, the troll crashes to the floor. The physical effects crew created destructive interaction on set with a pneumatic rig that swung a full-size practical cudgel and shattered balsa bathroom stalls.



For shots of the fallen troll, a full-size animatronic was constructed by Jim Henson's Creature Shop.

twist and turn very realistically.” The two pieces would then be attached with a CG neck stump.

Shooting motion control against a black background, Roger Guyett, Peter MacDonald and the Mill Film unit filmed Cleese in a number of mechanical rigs built by John Richardson’s team.

For the head-flipping gag, Richardson constructed

a metal frame to run up Cleese’s back, ending in a cup at the back of his neck– similar to a Victorian photographer’s neck brace– which enabled the actor to position his head in exact alignment to the camera for repeated takes. Chris Shaw programmed Milo moves based on the Nearly Headless Nick previsualization, and Guyett shot the body first, with Cleese wearing a black collar around his neck to assist digital head separations. A hinged metal arm, extending from the back of the mechanical rig, guided the motion of Cleese’s arm as he reached up to grab a marker at the top of his head, which was to hinge away from the right side of his neck. Mill Film then shot Cleese with a second motion control move in order to emulate the predetermined motion of his head swinging off. Rough on-set video composites guided head and body alignments. ILM artist Tia Marshall then matched and blended the Cleese elements against background plates, tracking in an interactive 3D collar, subtle facial deformations and a 3D neck-stump. “Part of what made it work,” said Legato, “was the fact that the kids did a good job of reacting to the effect. Chris is very gifted at directing children. He made it like a party for them.”

Assigned their house affiliations– Gryffindor, Ravenclaw, Hufflepuff and Slytherin– Harry and the other Hogwarts first-years disperse to their dormitories via an enormous marble staircase that slowly swivels to link up with another level, above which other staircases are shifting and reconnecting in an impossibly high tower. For closeups of students ascending these swinging stairs, John Richardson’s crew constructed a full-scale mobile staircase section. Supported by two wheeled bluescreen pillars and powered by a hydraulic motor, the structure could perform a ninety-degree arc inside a partial set at Leavesden.

For wider views, Legato and Mill Film choreographed a combination of live, miniature and digital set elements to expand the scene to epic proportions. Robbie Scott’s team built an eighth-scale, forty-foot miniature, laid on its side to aid construction and photography. “We did a lot of CNC cutting work to create staircase sections and vacuform fabrication for the steps,” said Scott. “We used glass-reinforced gypsum for walls, arches and doorways to create a plaster finish over the wooden carcass. We then dressed the walls with nine hundred miniature oil paintings, representing a gallery of Hogwarts’ ancestors.”

Rob Legato patterned the look for the Hogwarts gallery after the work of the Dutch master, Jan Vermeer. “We wanted a style of painting that was as real as a photograph, particularly in the faces,” observed Legato. The art department gave Scott’s team a selection of approved portraits, illustrating the desired painting style, to incorporate into the miniature. “We also created a lot of original art ourselves on the computer,” remarked Scott, “photographing extras in costumes, then giving the images a painted finish. We sculpted quite a few styles of frames, too, mass produced those in resin and gave them gold and gilded finishes. We built the model

The twelve-foot-tall creation was first sculpted in clay, then cast in silicone. / Subtle movement in the troll’s face and hands was achieved through the Henson Performance Control System. At the Creature Shop facility, artists Chris Fitzgerald and Daniel Auber do paint touch-ups on the troll as Graham High tests the animatronic controls.

with a removable staircase section, but it was otherwise solid and fixed in place; so Mill Film had to move their camera to create the illusion of movement.”

Malcolm Wooldridge and his team photographed the miniature based on a CG previsualization. Camera data from the miniature shoot then drove live-action photography on the full-size set, which was combined with bluescreen elements of live performers climbing stairs. “The shot starts with the camera low,” explained Karl Mooney, “looking at a stained glass window at the bottom of the model staircase, with bluescreened children tracked in. We start to tilt up and slowly rotate and, as we look up, the first four staircases are full-scale with live-action kids, shot with match-move data from the model shoot going to the rig. As the camera passes the students, it comes to the end of the model, and blends into our digital set extension, built using photographic textures of the miniature staircase sections. We replicated walls decorated with oil paintings, replicated staircases going up into infinity and tracked in more students. Then we added animated 3D staircases, rotating them on their bases and swinging them across to join one side of the atrium with the other. We lit everything with flickering light coming from CG lanterns built around the set.”

As a final detail, Mill Film and Cinesite added animation to the portraits on the staircase walls, with the painted characters spookily observing the influx of new recruits as they ascend the stairs. An overall sheen was also incorporated. “I visited a few museums and noticed the paintings had quite a sheen,” noted Rob Legato, “so any light source created kicks of light off the cracks and brushstrokes in the paint. That gave me the idea to take a canvas and cover it with bluescreen paint. We shot a test with John Seale who lit the paint to show off all the cracks and halation, then applied those textures to footage of bluescreen characters in period costume, blending them so they did not look like they were just sliding by under glass.” Paul Lambert, at Cinesite, composited haunted portrait performers with the painted patina by warping textures over moving objects, creating the impression of flowing paint effects. “We had one shot where a character walked up, blew out a candle, then the picture froze,” said Lambert. “We came up with a motion analysis technique that tracked each pixel in the image, then allowed us to extract that data and apply it to the textures- so as the people moved, it gave the impression that the paint itself was flowing with the character.”

Lessons for Harry and his classmates start on a small scale with pyrotechnic puffs and a floating, exploding feather generated on set by John Richardson’s physical effects team. During lunch in the Great Hall, students receive deliveries from home via owls that stream in through the windows, bearing packages and letters. Rhythm & Hues animated the flock of fifty-eight digital owls. One accident-prone student, Neville Longbottom (Matthew Lewis), receives a wizard learning aid in his care package from home. Called a ‘Remembrall,’ the pocket-sized crystal ball- which fills with colored smoke to signal its holder’s having forgotten something- was first created as a working action prop, but was ultimately revised by MPC as a more controllable digital effect. “We generated our CG Remembrall in Maya,” said Michael Elson, “and we developed a smoke particle generator for the appearance of the little cloud that forms inside it. For something so simple, it required a lot of rotoscoping in 2D, because the glass sphere was intricately etched. When the smoke appeared inside, we had to pull all the etchings away from the foreground, then lay them back on top.”

Action heats up for Harry and his fellow first-years as they assemble in the Hogwarts courtyard for their first broomstick flying lesson with Madame Hooch (Zo' Wanamaker). Filmed on location at Alnwick Castle in Northumberland, the flying lesson was one of the first scenes on the photography schedule. "We were under the gun with the flying lesson," remarked Legato. "The night before we started shooting, we were creating previz and editing it on laptops in the hotel room to help get a feel for the scene. We had the location Lidar-scanned, which gave us a detailed geometric map of the courtyard, down to all the bumps and wrinkles. We then took photographs and slapped them on top of that geometry, which gave us a three-dimensional model we could manipulate however we wanted. This allowed us to pick which parts of the scene were going to be CG and which parts were going to be shot on location or on a bluescreen stage with practical rigs."

Ultimately, the scene employed a number of practical flying broomstick rigs devised by the physical effects team. "In my first meeting with Chris Columbus, back in May 2000," recalled John Richardson. "I suggested building a pole-arm with a bicycle seat as a way to fly performers on broomsticks. We ended up building about a dozen versions of that rig, using just about every variation you could imagine. Our main rig was a hydraulic pole attached horizontally to a broom, with a seat at the end to support the actor. The attachment was adjustable, so the pole could swing in any direction- left to right, right to left, straight out, straight back, or at forty-five degrees. And each of those moves had three axes of movement- fore and aft, side to side, round and around. We then adapted that so the pole could be rigged from above or below the actor, for scenes where the kids were upside down or hanging from their brooms. All mechanical movement was hydraulically operated, driven by a Kuper motion control system. This allowed us to lock the broomstick moves or program moves as dictated by the previz. Most of our moves were done like that; though some were shot live, controlling the broomsticks through joystick controls."

Richardson's mechanical designers constructed the broomsticks from rigid steel to support performers' weight and withstand gravitational forces during moves. The pole-arm extended from sixteen to twenty feet, and was capable of performing a full rotation on its axis, while raising the performers twenty-five feet into the air. The physical effects crew could also mount the rig onto a track, allowing the central point of movement to dolly backwards and forwards during rotation and lift. Seats were, in most cases, mounted rigidly to the broomsticks, but were adjustable to allow independent movement for shots of the riders pulling their broomsticks up towards them as a means of reining them in. To ensure safety at all times, actors were strapped to the seats with climbing harnesses attached across the groin and at the back.

Trucked to the castle location and propelled by a portable hydraulic motor, the pole-arm rig, when positioned strategically to camera, allowed broomstick riders to fly with minimal need for digital rod removal. Other mechanical rigs used at Alnwick included a pole-arm mount built into the back of a six-wheel all-terrain vehicle- employed for a ground-level swoop- and a levitation rig for a scene in which Harry and the assembled students extend their hands over their brooms and command them, 'Up!' "Chris didn't want the brooms to look as though they were floating on wires," recalled Richardson. "So we built metal parallelogram teeter-totters with the broomsticks suspended between pulleys and fine wires. We had twenty-five of them in the wide shot, rigged from underneath the turf to lift the brooms in a very solid way."

When Madame Hooch instructs her students to mount their brooms, Neville promptly loses control of his and takes to the air. The boy's first moments of flight were accomplished live, at Alnwick, aboard one of the Richardson rigs; but as Neville zooms heavenward, the sequence



Owls deliver mail to students in the Great Hall. Rhythm & Hues produced both a low-resolution and a high-resolution owl for the show, the former 'feathered' simply with textures mapped onto cards, while the latter required the modeling of individual feathers. Other scenes featured live flying birds, shot both on set and on a bluescreen stage. / Hedwig delivers to Harry a Nimbus 2000, a high-performance broomstick the young wizard rides to victory in the end-of-term Quidditch tournament. Flying instructor and referee

foreshadows CG technologies that would be featured heavily later in the movie. Imageworks CG supervisor Seth Maury oversaw the digital aspects of the flying lesson at Imageworks, including shots of Neville flying above the castle, barnstorming students, bouncing and rebounding across the castle walls, then eventually becoming snagged on a statue, dangling momentarily before tumbling to the ground. Leaving her students

Madame Hooch prepares to toss the quaffle to start the game. A bluescreen element of actress Zo' Wanamaker was surrounded with computer generated towers, hills and skies. / The eight-and-a-half-minute Quidditch sequence, produced by Imageworks, was the end result of a yearlong research and development effort, and incorporated a full array of digital and practical effects. Quidditch players assume a circular formation at the start of play.

behind, Hooch whisks the injured lad off to the school hospital. Disobeying her stern orders, Harry takes to the air, defending Neville's honor by retrieving his Remembrall, stolen by the villainous young Draco Malfoy (Tom Felton). The twenty-seven-shot sequence showcased CG set extensions to extend battlements and add statuary, all-digital castle reconstructions cutting back-to-back with live castle environments, live motion control bluescreen elements and CG reproductions of Neville and Harry, performing tumbling, crashing feats well beyond human tolerances.

Character model lead Kevin Hudson and his team fashioned digital broomstick riders for use in the flying lesson. Skin technology was developed by Mark Lambert and Francis Liu, hair combing and dynamics technology by Darren Lurie, and cloth technology by Sho Igarashi, with animation supervised by Eric Armstrong. The development began with a simple test. "We did what we called 'the Pepé test,' " related Jim Berney. "Before our previz animator, Pepé Valencia, flew to England, we scanned his head, using very flat-lit textures of his skin. We warped the textures to make sure they would map onto flattened geometry, painted out any lighting details to create a very even texture, then allowed our 3D lighting to define its form." Mapped onto a 3D model, the digital Pepé demonstrated a workable concept for digital human production; and so Rob Legato commissioned Gentle Giant Studios to cyberscan the actors chosen to portray broomstick riders.

A substantial amount of effort was required to translate the young performers' skins to the virtual realm. "Those kids were like porcelain," commented Berney. "There was practically no skin texture because they all had soft English skin, maybe one freckle each and only a few veins. Mark Lambert and Francis Liu worked for months writing a very complex shader, relying on tricks with light and shadow to show underlying tissue. Harry was the most demanding character to model, because Daniel had the smoothest skin, the highest shot count and the greatest variety of costumes. His shiny black hair was also tricky to light, particularly in scenes where it lay flat, reflecting aniso-tropic highlights around the crown."

To test the effectiveness of their Harry model, Imageworks artists replaced Daniel Radcliffe's head with its 3D counterpart in a bluescreen composite being reviewed by Chris Columbus. "We didn't even mention that the head was digital," remarked Eric Armstrong. "We waited to see if Chris would notice something weird about it. When we told him what we'd done, he was thrilled; and that was when we knew we could give him a look that he could sell to the producers." To reduce the number of modeling duties facing the production, Gentle Giant scanned a variety of the actors' facial expressions. Modelers then worked closely with

Armstrong's animation team to hone actor cyberscans into a library of distinctive expressions. "We selected five or six expressions for each character, and built what we conceived as our bare minimum of facial models. The original plan was to utilize these characters for fast-moving distant shots. That changed, of course! We ended up using full-screen shots of Neville for when he was hanging from the tower. This was helped by the fact that the actor was so amazingly expressive. Every time we brought Matthew Lewis' face up on the monitor, somebody would laugh because of the way he expressed himself. But we never exaggerated him facially. The bottom line was always realism."

Though officially condemned, Harry's unsupervised broomstick performance amazes even his professors, earning him a spot as seeker on his house Quidditch team. In a subsequent scene, Harry is introduced to the Gryffindor team captain, Oliver Wood (Sean Biggerstaff), who explains the rules of Quidditch, the wizard world's favorite sport. Elements of the game include the quaffle, an indented flying medicine ball used for scoring points; bludgers, aerial cannonballs that can knock riders off their broomsticks, with sometimes fatal results; and the golden snitch, a darting, winged brass orb, whose capture by a seeker constitutes the winning of the game. MPC modeled the snitch based upon a maquette provided by the art department. "The snitch had feathered metallic wings that unwrapped from the sphere," explained Michael Elson. "Chas Jarrett animated them to hum like hummingbird wings, and made the whole thing flit about. As a detail, when the snitch took off, we added a reflection so you could see it in Harry's glasses. It was the kind of thing you'd notice if it was missing."

As the team's newest recruit, Harry finds himself the recipient of an anonymous gift- a sporty Nimbus 2000 broomstick, a lightweight prop carried to him during the next owl delivery by Gary Gero's live bird. Harry's delight is short-lived, however, when, on the night of Hogwarts' spirited Halloween celebration, the school is invaded by a twelve-foot tall mountain troll that attacks Hermione.

Production conceptual designers Robert Bliss and Paul Catling initiated the look of the troll. Nick Dudman and his team translated the resultant 2D artwork into 3D maquettes, producing white resin castings for digital vendors to scan, plus a color painted model that more fully illustrated the character's look and mood. "Stuart Craig's designers were well cast to the film," Rob Legato observed. "They were great at coming up with dark and fantastic creatures. The troll was both of



these. We wanted him to be ferocious, but we also wanted him to convey a somewhat dopey look with his eyes, so you hate him and don't hate him at the same time."

The troll's immense stature and bizarre proportions- a tiny head, massive torso, tree-trunk arms and clubbed feet- defied human form enough to predicate a digital approach to shots of the character's stalking corridors and cornering Hermione in a lavatory. After previsualization by Legato and Eric Armstrong, Imageworks CG supervisor David Smith oversaw digital effects for the scene, while Jim Berney and Legato accompanied the shoot, partially on location inside the eleventh-century Glou-cester Cathedral, but mostly in a lavatory set at Leavesden. John Richardson provided on-set interaction through a pneumatic rig that swung the troll's cudgel and shattered balsa bathroom stalls. For views through the troll's legs, Nick Dudman's team also built a pair of enormously heavy silicone trousers for six-foot-ten former rugby player Martin Bayfield to walk in.

The Henson Creature Shop contributed a full-size troll, complete with hand and facial animatronics, for shots of the beast after Harry and Ron have knocked him unconscious. "We scaled up the maquette and sculpted our twelve-foot-tall troll in clay," stated Jamie Courtier. "The sculpting was led by Jan Whittaker and Steve Jolley. Our troll was only seen laying down, but we sculpted him upright so he could be shot standing if Chris Columbus wanted. The natural displacement of the silicone made the flesh sag naturally either way. Kenny Wilson led molding to make the silicone skins. Graham High and Marie Fraser then fabricated an internal structure and gave him a state-of-the-art animatronic head, built by Adrian Parish and Dan Burnett, which connected to the Henson Performance Control System. This gave the troll face and finger movement, which Chris requested, so he could twitch and show signs of life that would scare you into thinking he might be waking up."

The Henson troll also became a source of reference for the Imageworks team as the character took shape in their virtual realm. "As soon as Henson's had an eyeball or a piece of skin," recalled Jim Berney, "they'd send it to us for our modelers and shader-writers to play with. Luckily, we did not have to match theirs spot-on, so we built a tremendous amount of detail into our digital version, with wrinkles and polyps and big, thorny warts." Referencing medical photographs, David Smith covered the creature's skin with a dense layer of carbuncles and grime, adding dirt to wrinkles and warts so that light could interact with subdermal layers. Hair also provided insalubrious detail. "We added little spotty tufts up on top of his head, gave him ear hair, armpit hair and a treasure trail going down his belly. No one really knew what he

One thousand background plates, shot on location in Scotland, were tiled together to create a photorealistic 3D setting for the Quidditch game, whose action was blocked out by Rob Legato with a lipstick video camera and a foamcore stadium model. / While digital players were inserted into the CG environment for long shots, closer views were bluescreen motion control elements of performers on pole-arm rigs. A team from Mill Film shot the bluescreen elements, importing Maya animation files from Legato's animatic into their motion control rig. / Distant spectators were computer generated. Footage of live people cheering and waving was reproduced and applied to a single virtual character, replicated to create a crowd of two thousand. / Harry hovers in midair- a bluescreen element inserted into the 3D set. Seamless tradeoffs from live to CG players were common from shot to shot, and often within a single shot. / Harry and an opponent dive perilously in game-winning pursuit of the snitch. Fans directed toward performers in the bluescreen setup created the illusion of high-speed flight, while smaller air jets at the rear of broomsticks enhanced billowing cape movement.

would be wearing. At one point he was going to have a vest, which developed into this complex patchwork with big stitching; but he ended up with a simple loincloth, so Todd Pilger put together a nice simulation to make the belly jiggle.”

Todd Wilderman and a team of five animators executed the troll animation, playing up its half-lidded dimwittedness while downplaying its strength. “The troll was a walking bulldozer,” related Eric Armstrong. “Knocking down a wall was like knocking over dominoes to him. We imagined he was like a four-year-old. Everything is very basic in the way a child that age reacts—either they’re very happy, or they’re very sad— and that’s just how the troll was, simple but extreme.”

As a means to integrate Daniel Radcliffe with the digital troll, Henson technical director Verner Gresty supervised creation of a six-axis motion base, linked to custom controls and software, on which Radcliffe could cling to a greenscreen troll shape in front of a bluescreen and tracking markers. Unfortunately, the shots involving Radcliffe and the motion base were cut for budgetary reasons, and Legato opted for a totally digital approach, animating a fully CG Harry atop the CG troll.

Flickering torchlight and flashes of lightning throughout the troll attack added another layer of complexity to the sequence. To create sympathetic lighting on the digital characters, Berney and Legato shot tiles of background plates during the corridor and bathroom shoots, from which 3D artists built orthographic motion picture maps of the moody sets. “We first shot tiles lit with random strobing light coming from the flambeaus,” said Berney. “We then shot another set of tiles, triggering each of the three lightning pots they had on set and shooting separate plates of each flash. We digitally stitched the flicker plates together to create one big flickering plate which gave us a single nodal point that we could pan around. Then, during the composite, we could mix in the lightning wherever we felt it appropriate, making light reflect across our troll.”

Thwarting the troll earns Harry and Ron house points and, by the time of the first Quidditch match, Harry has attracted many fans and one or two jealous rivals. Clad in Gryffindor’s red-and-gold wizard robes, Harry takes his place on the team as seeker— catcher of the golden snitch— riding out on his Nimbus 2000 to face the green-and-silver liveried Slytherin team. Rowling’s novel had described the Quidditch stadium as a field outside the castle, with three hoops like giant bubble blowers at either end, surrounded by spectator stands. Stuart Craig’s production design would expand Rowling’s concept to include twelve one-hundred-foot-tall observation towers, affording upper-echelon spectators aerial views, and ground-level bleachers draped with colorful banners and streaming flags, creating the ambiance of a medieval pageant.

The focus of a yearlong development effort at Imageworks, the Quidditch sequence ultimately featured an enormous virtual set and incorporated a dizzying array of digital and practical effects, choreographed and orchestrated by Rob Legato. “I learned a lot when I worked with James Cameron on *Titanic*,” remarked Legato. “The way Jim shoots action is very simplistic—much more simplistic than you might imagine— but he has a great editorial understanding of how an action scene should go together, making the sum-total of a group of shots feel like one flowing sequence. To do that, you can’t just randomly shoot coverage, then try to cut it together.

You have to have a sense of a scene beforehand, controlling all the rates of speed and shooting little two-second fragments that, when assembled, create one narrative. So, from the very start, I felt we could not conceive Quidditch in a traditional way- shooting everything practically, cutting it apart and piecing it together- and still create a sequence like the one you imagine when you read the book. Instead, we previsualized the game in its entirety, ignoring what could be achieved practically or not, and seeing what shots cut together to create an emotional response, then used that to define what moments we could shoot for real.”

Early in preproduction, Legato accompanied Stuart Craig on the location scout to Glen Nevis and defined the environment in which to situate the Quidditch stadium. “We built a tower in the middle of where Stuart had pictured the stadium would be set,” recalled Legato. “This gave us a generic overview- so we weren’t on the ground, we weren’t way up high, we were right in the middle, above the center of the playing field. Then we photographed the entire area with motion picture film, using a 27mm lens. We shot two-second bursts- panning, shooting, panning, shooting- and kept going like that all the way around, so we could seamlessly tile all the plates together to make a virtual 3D background that was photographically real. We shot everything back-lit and side-lit, so that everything would be lit uniformly. That way, when the camera cut to a reverse angle, we would never cut from back-light to a jarring front-light- which looks terrible, and has no depth- even though intellectually, it might be correct.”



During the Christmas holidays, when most of the students are home with their families, Harry and Ron stay at Hogwarts, exploring the castle environs. An exterior view of Hogwarts to establish the season made use of a miniature castle constructed on a stage at Leavesden by model unit supervisor Robbie Scott and his team. Designs for the model incorporated recognizable architectural features from several real-life settings used in the movie to represent parts of the castle. Mill Film shot the miniature, using motion control, then composited in backgrounds and digital snow.

The unpredictable Scottish weather added to the challenge of shooting sunlit scenery: but after one clear day in between torrential bouts of rain, shooting frantic twenty-minute bursts, Legato was able to ship a thousand background plates back to Imageworks. Jim Berney and CG supervisor Peter Travers quickly stitched together a digital cylinder of tiles from those plates, tracked in rough 3D geometry of the Quidditch stadium, and supplied Legato and previz animators Pepé Valencia and Jason McDade with a Maya file environment with which to commence blocking out their sequence.

"I like to work in an organic fashion," noted Legato. "Rather than storyboard a shot, I prefer to shoot something. The production art department had created a foamcore model of the Quidditch stadium to help conceive the sequence, so we shot that with a lipstick video camera, to help find shots that told the story. A character might fly from point 'A' to point 'B,' for instance, so we'd place our camera to cover where he'd enter and leave frame; and then that showed us where he entered the next shot. We did this until we built up a physical vocabulary of shots with a rhythm and a flow. We animated those shots, and I cut that to some heroic John Williams music to get a sense of how it might fly." The cut sequence inspired grander and more dynamic final shots, and eventually helped expand a half-page of screenplay into eight and a half minutes of screen time.

The Quidditch previsualization became the basis for a bluescreen shoot of broomstick riders, captured during the last three months of production by Mill Film's motion control team under Peter MacDonald, with Nick Davis supervising for Legato. Legato had returned Stateside to guide the previsualization team of nine animators in cranking out approved shots and motion control files as they were being filmed. Davis received the team's Maya files overnight from Los Angeles and passed them to Mill Film, which translated the data via its proprietary Rig Chaser program into its Cyclops rig. This enabled Davis to shoot three or four live-action setups per day, following the previsualization, which had been converted to exacting motion control files. "We mounted our Cyclops to a forty-foot-long track," said Malcolm Wooldridge. "John Richardson's crew mounted its broomstick rigs to six-foot 'baby tracks.' We then shot counter moves, with the broomstick moving towards us at about ten feet per second, while the Cyclops moved the other way, thus doubling the speed. John's programmer, Mickey Durkin, programmed the broomstick rig with Kuper software; then, once we programmed our move into the Cyclops, the Cyclops triggered the model mover, and the two moved together." The mountainous background was comprised of 360-degree tiles seamed together to produce a back-lit and side-lit-only lighting scheme for the game. Second-unit cameraman Gavin Finny created a template of the location of every shot in the stadium to ensure lighting continuity from shot to shot.

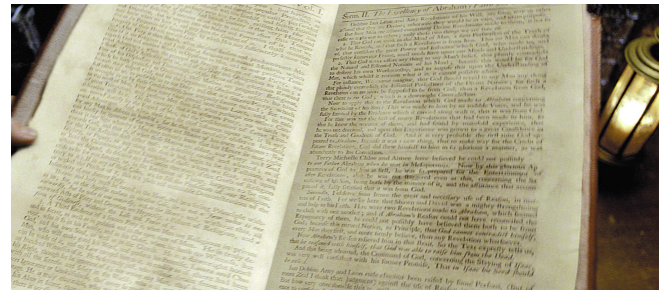


The gift of an invisibility cloak enables Harry to wander the castle unseen. During main-unit photography, Daniel Radcliffe wore a greenscreen cloak so that areas of his body to be rendered invisible could be extracted from the live plate. Effects artists at Smoke & Mirrors then provided digital enhancements, restoring backgrounds obscured by the actor and displacing those areas behind the cloak with a glass-like refractive effect.

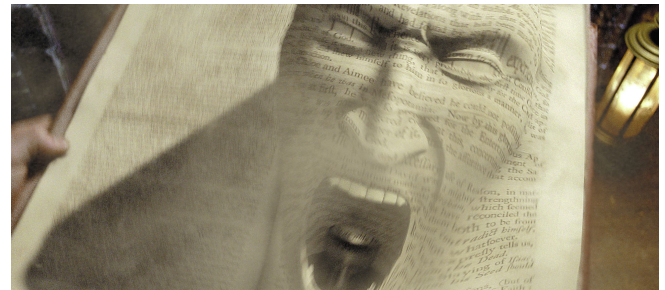
For shots requiring interaction between players, Richardson's crew rigged three pole arm rigs to 'fly' simultaneously within the thirty-four-foot-tall bluescreen cove. Two of them had full movement, the third had up-and-down with rotation only. All of the rigs were capable of being mounted from the top or bottom and- for daring live-action barrel rolls- from the back and front. Wind fans and air movers pummeled the actors, simulating the effects of flight, while smaller air jets attached to the rear of broomsticks enhanced billowing cape movement. Chris Shaw occasionally tweaked moves if the actors were unable to perform maneuvers swiftly enough, and often manipulated the frame rates to give the brooms a little extra oomph. "We sometimes started off a shot as low as six frames per second," noted Richardson, "then we'd ramp up to fourteen during the take, to enhance the sense of acceleration, then level off at twenty-four. It was a mixed batch of tricks."

The complexity of the bluescreen shoot required considerable planning and organization, especially given the restricted schedules of the young actors. "We were constantly up against the number of work hours that we had with the children," said Karen Murphy. "Some of them were in the nine-to-eleven-year-old category; some were eleven-to-thirteen; some had 'A'-level exams coming up, and nothing could hold them back from that. So we had to deal with British Actors Equity child labor laws, which are actually stricter than American laws. Our bluescreen production manager, Marcia Gay, was instrumental in keeping all of that organized."

As physical Quidditch elements emerged from England, Jim Berney and Peter Travers were assembling the environment into which the bluescreen players would fly. "We had never used a virtual background to this degree before," Berney commented. "Some of our moves were full quarter-mile translations, with 180-degree camera moves, so we had to come up with a level of detail that would allow for parallax shifting between the Quidditch towers, the mountains, the clouds and the castle." After assembling the jigsaw puzzle of background plates, 2D artists stitched together tiles, color-correcting and painting textures to generate a seamless 3D dome



Cloaked in invisibility, and in search of answers to some gnawing questions regarding Hogwarts history and his own strange heritage, Harry sneaks into an off-limits section of the school library and opens a forbidden tome. To his shock and dismay, he discovers that the book has a built-in intrusion alarm when a screaming visage lunges at him from within it. Working from production conceptual art, artists at The Moving Picture Company animated the face to extrude through a page of text, then tracked the imagery to the prop book used in the scene, which was fitted with a greenscreen page.



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that could be projected onto the geometry of the terrain. “We modeled the mountains in 3D so they had parallax shift between them, and modeled a lip at the edge of each mountain with painted transparency maps to create a broken edge at the tree line, into which we blended digital trees. Some of our tree textures were part of our live-action plate, baked into our projected mountain; but we also built 3D trees in Houdini, matching the tree line and fading them into the trees behind them. We didn’t think we were going to be able to utilize sky textures from the plates, because there were so many clouds; but when we started looking elsewhere, nothing matched the perspective or the feel of the skies in our background plates. We finally found what we had been looking for in the tiles and, with a lot of painting, we were able to create a dome of sky that held up pretty well, sometimes adding cloud elements shot by shot.”

To plug Hogwarts into the virtual terrain, Nick Davis and Mike Kanfer provided Berney and his team with locked-off motion picture tiles of the castle miniature, shot from eight different angles, offset at varying heights. Imageworks then roughed out 3D castle geometry and mapped textures onto that at ‘match-move detail’- enough to see a perspective shift when panning by in long shot.

The final design for the Quidditch stadium took shape just prior to the bluescreen shoot. While shooting closeups of the spectators in the stands and the tops of observation towers- a single set, redressed- Stuart Craig added canvas façades displaying school insignia to give the wooden structures an additional splash of color. To incorporate the giant fabric sheets into the digital set already under construction at Imageworks, Berney and Kanfer shot flat-lit photographic reference of each canvas. 2D artists then retouched the textures and added stain maps in RenderMan. Sho Igarashi applied these textures to 3D cloth simulations and animated canvases to ripple and billow as wind- and sometimes out-of-control broomstick jockeys- contorted the heavy fabric.

David Stephens supervised the production of a digital Quidditch crowd, generating two thousand virtual spectators- one thousand in the lower stands, one thousand in the upper towers- from a single procedural primitive. “We shot reference snippets of people cheering, head turning, waving,” explained Peter Travers, “then we mimicked these movements as ‘rotomation’ and applied them to a single crowd character. This character was completely virtual, programmed with every kind of movement and every kind of prop that any crowd character could have. We then programmed RenderMan to replicate a crowd with levels of detail depending on the characters’ proximity to camera; so if they were closeup, they would be full-detail, high-resolution people, but if they were in the far distance they would be simple spheres. RenderMan would only render areas it could see in the frame. If we had tried to render the whole stadium high-rez throughout, we would never have been able to manage all the data.” To further optimize computer hard drive space, Stephens wrote dynamic shared object code to postpone population of Quidditch stands until render time. Animators choreographed crowd reactions by dialing in selected actions, programming waves of turning heads to follow the moving targets. RenderMan later generated swathes of tiny characters that followed broomstick action above the field of play.

For aerial derring-do beyond the capabilities of the live bluescreen performers, Eric Armstrong's team animated fifteen CG characters for the Quidditch match- including a virtual Madame Hooch as ground-level referee, and seven players per team. Characters were modeled from cyberscans of broomstick riders and key-frame animated through forward and inverse kinematics, allowing animators to hand-animate or procedurally simulate thrust. "We tried to make the broomsticks fly as if each one had a rocket pack on board," Legato related. "We wanted them to behave aerodynamically, so it really felt like you had to steer them. If a character was flying straight, then had to make a sudden turn, the broomstick couldn't just hop to one side. The rider had to brake like a police car performing a hand-brake turn, then the broomstick would slide and inertia would pull it back. We wanted there to be a sense of physics."

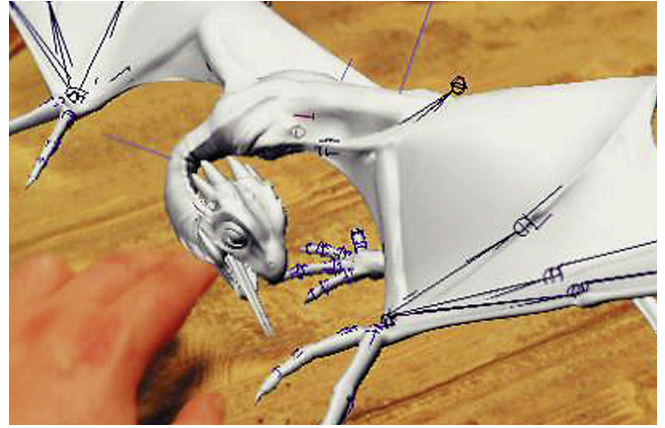


While visiting Hagrid in his hut on the Hogwarts grounds, Harry, Hermione and Ron witness the birth of a baby dragon. On the giant's kitchen table, the hatchling breaks out of an egg, takes its first wobbly steps, then lets loose with a fireball sneeze that singes Hagrid's beard.

Data from the Quidditch bluescreen shoot was used during the animation process, occasionally requiring interpretive skills to translate motion control moves back into the 3D world. "A lot of times, the bluescreen elements lined up perfectly," said Jim Berney. "If they departed from the previz, we tried to use the encoded data; but it was often easier to get the flavor of the shot by tracking a match-move and then manipulating the shot in 3D. At least twenty of our Quidditch camera moves blended encoded data, motion control data, match-move and freehand data; then we added another move on top of that in our composite, to give the scene a little drift."

The interplay between live-action and CG also played a crucial role in the simulation of broomstick riders' hair and costumes. As successful as Imageworks' fur and fabric simulation had been on *Stuart Little*, the long flowing capes and hairstyles on display in Quidditch called for new combing and dynamic tools, particularly when applied to gravitational forces of *The Game*, which averaged speeds of 100 miles per hour. "We spent a long time animating the Quidditch characters without cloth," said Eric Armstrong. "When we put the cloth on top, it became this wild and crazy thing, moving all the time. We found that we had to be careful to keep the performances very understated and humanistic, because the cloth simulations were driven by reality. There was a little speedometer at the bottom of our screens so we could tell how fast the characters were moving, and what direction they were traveling. If we exceeded 300 miles per hour, it would literally rip their clothes off and leave them behind at the other end of the field!"

Berney's technical team fine-tuned simulations, adding manual controls to blend digital 'noise' into procedural dynamics to alter the flap of fabric and riders' hair. Armstrong's animators added cheek-flap for foreground flybys, and occasionally match-cut from live to digital riders in one shot. "There's one shot in particular," said Armstrong, "where the camera follows a female Gryffindor character as she's flying. She was a bluescreen girl, but the specifics of her performance weren't quite what Chris Columbus was after; so we switched her out by having another character wipe past- and she's digital from there on, still just as close to camera. We had to hand-match her ponytail and the contours of her fabric exactly at the moment that we cut, but hopefully you'll never know the difference."



Artists at Rhythm & Hues digitally replicated a prop egg rigged on the live-action set by John Richardson, then animated a CG dragon to break out of it. The digital model was set up to include wrinkling skin and stringy muscle deformations.



In the final composite, the fully rendered hatchling, lit to match plate photography, reacts to Hagrid's gentle touch.

Another complex bluescreen/CG handoff occurs at the climax of *The Game*, when Harry, after racing neck-and-neck with the Slytherin seeker, rides his Nimbus 2000 surfboard-style to capture the elusive snitch just seconds before wiping out and plowing into the ground. The series of shots utilized live bluescreen photography up to Harry's impact, at which point animation took over, referencing live-action. Mike Kanfer filmed, at 96 frames per second, stunt performer David Holmes on a skateboard being towed behind an all-terrain vehicle. Holmes took a dive from the skateboard into crash-mats. Imageworks animators then rotoscoped the footage, completing Harry's fall and gouging the virtual terrain, which was turfed with almost a billion blades of Maya grass and animated to flatten, squish and spring back to a specified percentage.

Supervising assembly of the 2D elements for Quidditch, Seth Maury employed Imageworks' new in-house compositing tool, Bonsai, which facilitated the close interaction of 2D and 3D departments at the studio. "In all our shots, the compositor and the 3D artist were the same person," remarked Jim Berney. "We have found that by teaching our 2D artists to do 3D, and our 3D artists to do 2D, a single person tends to have better control and knowledge of whether it's better to re-render or try to make an element work." Maury's duties included generating the 3D game props- namely the quaffle, bludgers, bludger bats and snitch- all of which were modeled and mapped from live reference. Completing the atmospheric effects, David Stephens created flights of tiny birds, animated through behavioral dynamics to flock above the playing field.

The final 145-shot extravaganza included forty crowd shots featuring closeups of the spectators, assembled by Cinesite in London using bluescreen inserts of onlookers in stands, composited against Imageworks' virtual landscape. The shots were turned over to Imageworks in mid-June 2001, leaving only four months to complete the vital sequence. Visual effects producer Crys Forsyth-Smith and digital producer John Clinton faced the daunting task of scheduling a crew of more than one hundred to final the shots in record time.

Kanfer oversaw color timing of the composites and the final stage of Quidditch postproduction, which required collaboration with John Seale in order to match first-unit photography. Seale shot all daylight scenes for the movie with an '81A' straw-colored warming filter to infuse the bleak English winter light. All Quidditch elements- both bluescreen and CG- had been deliberately shot unfiltered so as not to affect bluescreen separations. By digitally simulating the 81A filter in the final film output, Imageworks gave the Quidditch tournament an appropriately romantic, golden glow.

Though many of the students return home for the Christmas holidays, Harry and Ron remain behind at Hogwarts. Harry finds himself unable to master Ron's favorite game of wizard chess- played on an enchanted chess set that featured a four-inch-tall argumentative White Queen brought to life with digital animation by Mill Film- and turns his mind instead to exploring Hogwarts. Donning an invisibility cloak received as a Christmas gift, Harry explores the castle corridors at night. Legato awarded the invisibility assignment to Sean Broughton at Smoke & Mirrors, seeking a magical but fleeting vanishing effect that would impose minimal restrictions on first-unit photography. Broughton illustrated a conceptual approach, shooting an in-house

test of a bespectacled Smoke & Mirrors employee robing and disrobing with a piece of greenscreen silk. Digital artists keyed ranges of specularity, then created shimmering refractive textures to mask and reveal the subject.



As part of a search party sent into the Forbidden Forest to locate an injured unicorn, Harry stumbles upon the evil Lord Voldemort drinking the magical animal's blood, but is rescued from consequent harm by the centaur Firenze, who drives the dark wizard away. Though establishing views of the forest were filmed on location, shots involving the practical unicorn, a Nick Dudman prop, and the CG centaur were captured on a stage set dressed to represent a section of the eerie woods.



Closeup shots of the centaur, created by Sony Imageworks, required artful and seamless integration of live-action and digital elements and careful attention to performance issues. Animators studied video of the centaur voice performer to pin down vocal nuances and subtleties of facial movement.

To capture production plates for the vanishing act, Legato shot scenes of Daniel Radcliffe veiling himself with a two-sided cloak- one side patterned in a complex design of magic symbols, the other a vivid green. To record background plates, Mill Film covered one of the Harry disappearances with its motion encoded Arri head. At another location where motion control was not available, Legato shot locked-off background plates for tiling. Smoke & Mirrors then set to work extracting greenscreen separations and animating invisibility composites. "We generated clean mattes in Inferno by keying highlights, midtones and lowlights," explained Sean Broughton. "We built our texture maps from there and displaced backgrounds behind the cloak with a glass-like effect using a 5D 'Glass' spark and a Sapphire 'Lens' spark. We increased or decreased the refractive index depending on the speed of the cloak; and, once it settled, it became completely transparent. We then assembled our tiled background, match-moved that to our main plate, treated that with the glass effect and mixed the textures in against the green area of the cloak."



The virtual character was groomed using Imageworks' latest fur and surfacing technologies.

For a scene in which Harry holds a lantern out from underneath the cloak, Legato shot Radcliffe wearing a green armband. Smoke & Mirrors keyed out the green section, painted Harry from the scene and animated subtle refraction effects to simulate fluctuations in the density of the cloak in time with the actor's steps. For subjective invisibility points of view, the camera department rigged a sheer version of the cloak as a scrim to veil the Steadicam lens on set.

Seeking information about an ancient wizard and the history of the school, Harry sneaks into the restricted section of Hogwarts' library and pulls down a foreboding book, which comes to life in his hands. The property department dressed the book with a greenscreen page, then MPC generated a 3D humanoid face, based upon art department conceptual art, and animated it to scream and extrude through a page of text, tracked to the book in Maya. Harry flees the library and ducks into an unused classroom where he finds the tall and ornate 'Mirror of Erised.' Removing his cloak, Harry sees not only his own reflection in the glass, but also his parents, peering eerily back at him over his shoulder. Mill Film encoded Super Technocrane moves for the scene, shot on location at Lacock Abbey, in Wiltshire, capturing separate passes of Radcliffe and the two other actors. Mill then assembled the composite, adding diffusion layers and a tarnished patina to the mirror's antique surface.

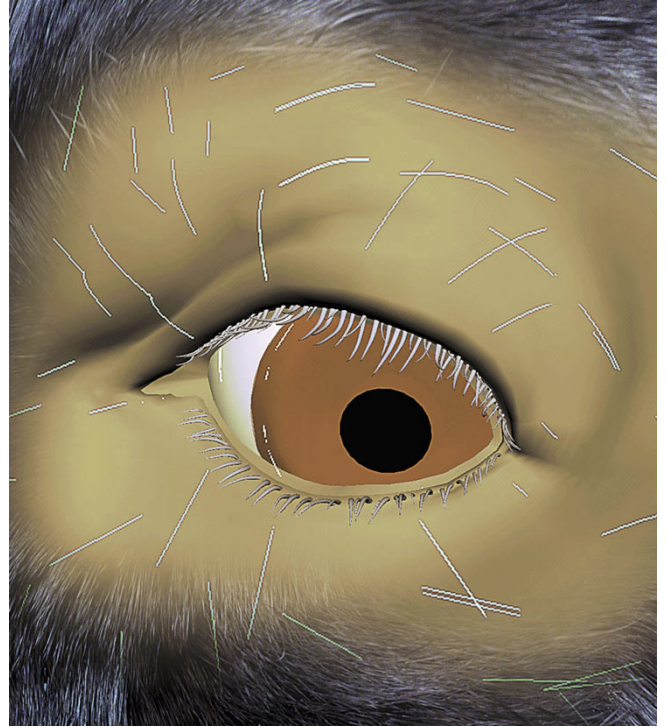
As Harry ponders his encounter with the mirror, the narrative takes a leap in time- first following Harry as he walks through snow outside Hogwarts, Hedwig on his arm, then following the bird as she takes flight over the castle, winter melting into spring. Gary Gero began the shot

with Oook the owl perched on Daniel Radcliffe's outstretched arm, the young actor wearing a protective covering beneath his sleeve to shield him from the bird's claws. Artists at Rhythm & Hues match-cut the live owl to their high-resolution digital double, animating the bird to shift its weight then perform a rapid wing spread, which morphed to a flying model as it swooped from Radcliffe's arm. The bird re-enters frame as the camera rises over Hogwarts. The scene was filmed partially on location at Durham Cathedral, and partially by Mill Film using a fifth-scale section of the cathedral's roof constructed by Robbie Scott's crew and dressed with salt, when upper levels of the location proved to be inaccessible to live-action fake snow dressing. As the winter background dissolves to spring, the camera descends over the 1/24-scale Hogwarts miniature, digitally enhanced by Mill Film. "We added an actual sky that we shot at Shepperton," remarked Karl Mooney, "then we added sections of painted landscape, cloud shadows on the landscape, bluescreen children, CG birds, people at the castle windows and moving sky reflections in the window glass. We did a lot of matte painting on all of our miniature Hogwarts exteriors, adding textures and shadows to break up highlights and imperfections. It really brought the shots to life."

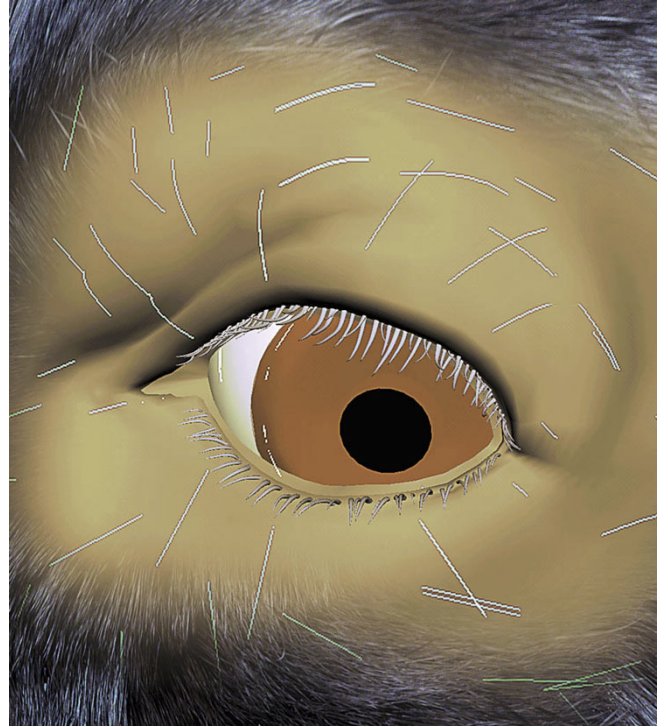
Spring brings a new arrival- a large speckled gray egg from which a dragon hatchling emerges on Hagrid's kitchen table as Harry, Hermione and Ron look on in amazement. Although the role of the dragon, named Norbert, was reduced from a longer episode in the novel, the tiny creature was designed to closely resemble Rowling's description, which likened him to 'a crumpled, black umbrella.' Working from a maquette by Paul Catling Richard Hollander's team at Rhythm & Hues scaled the dragon to a length of eighteen inches, then modeled him in 3D, with Mark Rodahl and setup team head Will Telford devising wrinkling skin and stringy muscle deformations. Rob Legato photo-graphed background plates in England, with John Richardson motivating movements of a large prop egg on set by directing air jets across Hagrid's tabletop. Rhythm & Hues digitally replicated the egg and animated it to crack with a small gaseous explosion. "You first see one arm burst out of the egg shell," said Hollander, "then he climbs out, very wobbly, staggers, slips on a piece of eggshell, begins to sniffle, then sneezes, producing a fireball that singes Hagrid's beard. Chris Columbus wanted us to play the scene like when a little kid pees and people think it's cute. Norbert is very sweet and innocent, even though he's a dragon, and Hagrid just loves him. He had a bony little rib cage and some nice iridescence on his back, little chicken feet, wet and leathery bat wings, a body like a lizard. We gave him double lids on his eyes, a set of horns on the back of his head, a little pointy tongue, a nice tail that he could swish, and a very bendy neck." Craig Talmy supervised the Norbert animation in Voodoo; Pauline T'so lit and rendered the creature in Houdini and Vman-tra; and Harry Lam assembled elements in the studio's homegrown compositing program, Icey.



Shaken by his encounter in the forest, Harry resolves to keep Voldemort from stealing the Sorcerer's Stone- known to be hidden somewhere at Hogwarts- thereby regaining his lost powers and achieving immortality. Having deduced that the stone is hidden in a chamber beneath a trap door guarded by a giant three-headed dog, Harry and his friends cautiously approach the beast. Seen in extreme closeup, the CG canine was animated by Sony Pictures Imageworks and imbued with ultra-lifelike details such as moist tear ducts, eye highlights and reflections, and expressive brows to sell the illusion of its being a real animal. Although all three heads were attached to a single body and exhibited typical canine behaviors, animators individualized the performances so that each possessed distinctive traits and personalities.



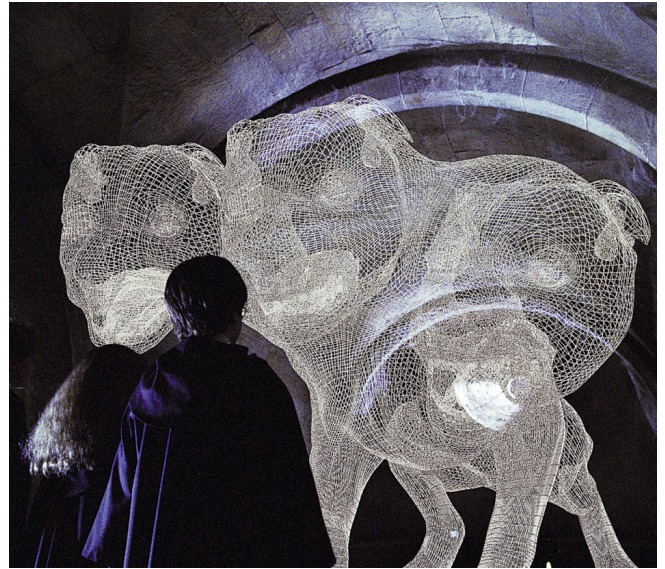
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Harry's unauthorized explorations of the castle land him in hot water. Tagged for late-night detention- together with Ron, Hermione and Malfoy- he is paraded out to Hagrid's hut and ordered to track down an injured unicorn in the Forbidden Forest that borders the castle grounds. For establishing scenes of the forest filmed in Black Park, a 530-acre wood close to Pine-wood Studios, John Richardson's team laid a system of flat tube pipes through the trees, which introduced a constant flow of mist to withstand prevailing winds. A shroud of fog was created by blending the mist with dry ice at ground level. As Harry and Hagrid discover a trail of silvery, reflective unicorn blood, the action switches to a section of the forest re-created inside a soundstage. Legato simulated pools of unicorn blood with bluescreen paint, into which actor Robbie Coltrane dips his finger. CFC extracted mattes from the paint, rotoscoping the liquid, and digital artist Victor Wade built a reflection map of the forest from photographs of the set in Photoshop. Dominic Parker projected the reflection map onto 3D Houdini drips and puddles, composited in Shake, then hand-painted liquid geometry onto Coltrane's finger for Hagrid's finger-dip.

Harry follows the trail of blood to a lifeless unicorn, splayed on the ground underneath a shadowy figure that speedily flits away. John Richardson created the hooded figure's serpentine departure as a wire-pulled practical effect, executed in collaboration with the wardrobe department, while the Nick Dudman team fashioned the unicorn as a full-scale prop. "We built the unicorn from scratch," Dudman stated. "We based the creature on a breed of pony that Chris Columbus liked the look of, then John Coppinger produced a maquette and sculpted the character full size. We molded that, produced an articulated skeleton and fabricated a muscle suit. We made the skin out of Cono-thane, which is an



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absolutely lethal chemical but has a wonderful heavy flesh quality we could apply fur to by flocking. I didn't want to try it in silicone, because I was afraid the fur wouldn't adhere." Esteban Mendoza furred the unicorn's main surface areas, shooting white fur fiber through an electrostatic flocking gun. Astrid Akserellian and Mel Lanihan punched detail hairs and hand-laid an albino tail and mane, then Coppinger applied a resin horn.

While viewing the slain unicorn, Harry is startled by another mythological creature, a four-legged equine/human hybrid that leaps from the undergrowth and scrutinizes him with a solemn gaze. Realized as an entirely digital character at Imageworks, Firenze was deliberately designed to avoid common preconceptions of a movie centaur. "We wanted Firenze to be more like a horse that had human qualities, as opposed to a half-horse/ half-human," said Rob Legato. "We wanted his physical structure to extend into his horse anatomy, as opposed to cutting off a horse and cleaving a man on top. We also didn't want him to have a two-tone quality, with horsehair extending only so far, then suddenly he's a guy. Even if we had attempted to blend an actor with a CG horse, that would have presented problems- how do you shoot it practically? There was no way to create this character other than completely digitally."

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Lulling the guardian dog to sleep with music, the trio leaps through the trap door and into a giant pulsating plant called the Devil's Snare. Nick Dudman and crew built the plant using cargo netting stretched across a set and dressed with an assortment of silicone vines and tendrils. Mats beneath the netting cushioned the falling actors, while puppeteers operated the clutching tendrils from below.

Part pagan satyr, part stallion, Firenze was modeled after the Friesian breed of horse– a powerful, elegant animal of Dutch and Arabian lineage, known for its majestic, prancing gait. The art department created a maquette of the centaur in clay, then passed that on to Kevin Hudson and Eric Armstrong at Imageworks, who scanned the sculpture and began to build their 3D model, referencing Friesian horses studied at a breeder’s ranch in Los Angeles. “I was pushing to make him a little more equine than he ended up,” allowed Legato. “My point of view was that ours was the real thing– not the whitewashed version we’ve all seen in illustrations and books.”



Free of the plant, Harry mounts a broomstick and draws upon his talents as a Quidditch seeker to snatch a winged key from a flock of dive-bombing keys, enabling Hermione to unlock the door to another chamber. Rob Legato filmed the live-action on a set consisting of partial walls masked with greenscreen above. Rhythm & Hues extended the walls digitally, then inserted CG keys, defining their flight with the aid of a behavioral animation system.

Legato prepared for the centaur shoot in England, concentrating on the close interaction of Harry with the virtual character. “We had a fairly complicated shot,” Legato recalled. “We started it with an over-the-shoulder of Harry, with the centaur walking towards him. The camera then went all the way around Harry and passed behind the centaur’s head to show what he’s referring to– which was the dead unicorn. We then continued the rest of the way around to end up in a profile shot of Harry, which Firenze then reenters, with dialogue throughout. So it was very carefully choreographed.”

The MPC/BBC/Panavision camera tracking system proved an important tool in orchestrating the complicated camera move. Three months before cameras rolled on the centaur sequence, Michael Elson and Peter Muyzers had introduced the tracking technology to Rob Legato at MPC. “As soon as I saw it, a bell went off,” recalled Legato. “I realized that it would be very useful not only for this project, but for the next three Harry Potter films. The only way to get a handle on a seamless and organic integration of live-action and visual effects is to be able to previsualize. Being able to see an effect on set the day you shoot lets you take that to another level. In a couple of years, films made without this degree of integration will look rather stiff. Effects in general are now becoming more a part of the overall filmmaking process.”

Prior to the shoot, MPC installed 350 tracking markers above the forest setting to reflect infrared signals from the camera. Air View Systems recorded a detailed Lidar scan of the stage, producing a Maya file that described the rough geometry of the set. Legato utilized this data to build a 3D model of the forest, then introduced a rough polygonal version of Imageworks’ 3D centaur and animated timings based on a reading of the voice track. Jim Berney also placed traditional LED tracking markers around the set as backup, then Peter Muyzers calibrated cameras and cued Legato’s previz with the tracking system.

Employing a series of custom plug-ins for Maya Real Time, Muyzers broke down the centaur’s performance into a series of ‘hot keys’ on his computer keyboard. “If ‘F1’ was our hot key,” stated Muyzers, “when we hit that, it might trigger the centaur to step forward. If the director then said, ‘Centaur stop,’ we’d hit ‘F2’ and he’d stop walking. ‘F3’ could make the centaur’s

head bend forward. We came up with a range of moves with Rob; and we could trigger any one at any time, in real time, and the crew could see it happening, composited with the actor on the video tap. Danny Popkin from the BBC worked with me on set to provide technical support. We gave the camera operator a pair of virtual reality glasses so that he could view the previz on two little LED screens. It was a bit gimmicky, but he loved it because it meant he didn't have to turn his head away from camera to see what was going on." With a bit of rehearsal, Daniel Radcliffe mastered the timings of the complex camera move; and by day's end, Legato had completed all five setups featuring the CG centaur.

Back at Imageworks, Kevin Hudson refined the 3D model of Firenze to fuse a shortened human torso to a muscular Friesian body. Hudson and lead centaur animator Jeremy Cantor studied footage of a horse leaping over camera- shot by Mike Kanfer as specific reference for the centaur's entry- and made use of video footage of Firenze voice performer Ray Fearon to pick up nuances of his facial characteristics and resonant, whispered voice. "Ninety-five percent of performance animation comes from the dialogue," noted Eric Armstrong. "The highs, the lows, the emotions, all come from the voice. With Firenze, who was talking full-screen, nose-to-nose with Harry, it was especially demanding because viewers were subconsciously comparing him to live-action right there in the scene. We had to be very careful to add subtleties- little things like the way a person's eyes move back and forth as they look into another's face. Our centaur animators really had to understand human motion and bring that out in the performance." Rendered and groomed with fur technology devised for RenderMan by Mark Lambert, the centaur combined all of the surfacing technologies developed by Imageworks for the film- translucent human skin, a glossy pelt, a long tail, a wavy mane and a beard.

Harry's meeting with Firenze confirms his fears that the evil wizard, Lord Voldemort, has returned to Hogwarts and is plotting to possess the Sorcerer's Stone, a hidden orb that will restore his vastly diminished power. To prevent this, Harry, Hermione and Ron resolve to obtain the Stone themselves and, after completing summer exams, they don Harry's invisibility cloak and enter a forbidden chamber. Glimpsed earlier during one of their exploratory missions, the room contains a trapdoor guarded by a ferocious creature- a twelve-foot tall, three-headed canine known as Fluffy. "We wanted Fluffy to look as much like a real dog as possible," commented Rob Legato, "even though he was enormous and had three heads. We wanted him to be more like something from Ripley's Believe It or Not, rather than a bizarre mythological beast. The gag was, when we first see him, we'd just see one head without size reference- then, as we panned across, we'd see a second head, then a third. Finally, when he stood up, the camera would tilt up further, and we'd realize that he was this twelve-foot monster dog."

Robert Bliss initiated the Fluffy design based on Rottweiler physiognomy, then Nick Dudman's moldmakers made a resin maquette and passed it on to Imageworks, which animated the character digitally. The Dudman team also created a giant-size animatronic paw for actors to grapple with, and John Richardson provided explosive shattering trapdoor effects for the climax of the scene. But,



In the next room, Ron's mastery of wizard chess is tested by a bigger-than-life version of the game

from the outset, Legato planned Fluffy as a CG creature to delineate its unique anatomy- three heads coalesced into one central spinal column- which posed certain biological conundrums. "At one point we see Fluffy sleeping," explained Eric Armstrong, "and Chris Columbus wanted Fluffy

snoring. This raised the question, did all three of Fluffy's heads snore at the same time? We came to the conclusion that Fluffy had three heads but one chest, and hence one set of lungs, so all the heads would snore at once. That answered that. But then we decided that since Fluffy had three heads, and hence three brains, we would give each head a different personality. Fluffy's head on the far left was the leader- he was more calculating, but reacted less because he was thinking more. The head on the far right was the aggressive one- he was not as fast on the uptake, but he was very quick to attack. The head in the middle was the dimwitted one, and it always took him a while to catch on to what was going on."

Paul Jessel, an experienced stop-motion animator, led the team of four Fluffy animators, which united the performance of the three heads with typical canine behaviors such as subtle ear twitches and facial ticks. Mark Lambert and Seth Maury oversaw look development of Fluffy's lustrous coat, combing swirls of fur around the creature's chest and the contours of its muscles. "We spent quite a lot of time figuring out the scale of Fluffy's fur," noted Murray. "We went through many iterations trying to determine how carpet-like it should be for a dog ten times normal size. We ended up cheating his scale by cloning textures to cover his massive surface. It would have taken forever to render every strand of fur to make him look that plush."

Digitally simulated dust and drool enhanced the dog's monstrous size- puffs of dust rose with his footfalls, while spittle and saliva swung from fleshy membranes between his teeth and gums. "Whenever Fluffy opened his mouth, we added 'stringers' inside," said Jim Berney. "We also paid special attention to his eyes. The first thing I brought up when I started on this project was that CG eyes have always looked fake to me. We discussed this with all the modelers and physiquers, and we decided that what CG characters had frequently been missing were lacrimal caruncles- tear ducts! Underneath the tear duct, you also have the semilunar membrane, then a thin meniscus layer of moisture at the contact between the eye and the eyelid that creates a highlight. Usually, that's all missing in CG, and instead you see this perfect cutout around the eye. That's why most CG characters look dead." Imageworks added tear ducts, eye moisture, eye highlights and eyelashes to all their CG characters, seen in giant detail on Fluffy.

Squeezing by the monster canine, Harry, Hermione and Ron jump through the trap door and fall into the clutches of their next adversary- a gigantic, pulsing plant known as the Devil's Snare. Though featured in the novel, the Devil's Snare was not included into the film story until late in the shooting schedule. Close to finishing the show, Nick Dudman quickly regrouped his animatronics team, placed Gary Pollard in charge of construction and fabricated the forty-foot-wide plant puppet in eight weeks. "We sculpted and molded every piece," explained Dudman, "and made multiple castings in silicone. Chris Barton led the build of what we called 'soft mechanics'- cables inside silicone- which were suitable for the actors to fall into. We strung a wide-mesh cargo net across the set, dressed our tendrils and tentacles and vegetable matter

that must be won before Harry can move on to the final chamber. Stuart Craig oversaw the design and construction of the towering chess pieces- playing into their roles were lead artists interacting with practical pyrotechnics rigged by John Richardson and filmed on the live-action set. and engage in mortal combat.

onto that and put crash mats underneath. Walking on it was exactly like walking on the webbing between two hulls of a catamaran- the whole thing could swing and shift. We filmed a lot of reverse gags, pulling vines off actors, so Rob could print these in reverse and make the vines appear to latch onto people. John Richardson also rigged some of our plant tentacles with compressed air to make them thrash about; but we puppeteered most of it from below, with a team of forty people dressed in black. It was very silly, but the kids thought it was great- like the bouncy castle from hell!" To lend the scene a moist, tropical atmosphere, MPC later rotoscoped vines, and added glistening highlights and digital atmospheric effects.

Having escaped the Devil's Snare, Harry, Hermione and Ron next encounter a locked door inside an arched chamber, hewn from rock. Shafts of moonlight illuminating the chamber reveal what at first appears to be a flock of exotic birds, gliding overhead. Harry spots a broomstick nearby and realizes the birds are in fact flying keys, one of which he must retrieve to unlock the door. Mill Film previsualized the sequence, which Legato filmed in a partial set, with walls extending eighteen feet and greenscreen above. Rhythm & Hues provided digital set extension and 3D flying keys. "We modeled the flying keys from an art department prop," explained Richard Hollander. "We made a flock of six-inch gold-metal keys with pearlescent wings, and one smaller, rusty pewter version that we called the 'gimpy key' because it had a broken wing. The gimpy key can't fly straight; and when Harry sees it, he guesses it's been used to open the door before. The other keys start off flying gracefully- Chris Columbus used the word 'bucolically'- ten feet above the children's heads; but when Harry touches the broom, the bucolic keys attack like kamikaze dragonflies, and Harry has to ward them off as he chases after the gimpy key."

Sequence supervisor Bob Mercier and effects animator Andrew Chiang created flapping cycles for the airborne keys, then applied these to a behavioral system that replicated animation in up to three hundred spiraling, dive-bombing keys. "We defined the physics of how the keys would fly around obstacles in the set," stated Hollander. "The behavioral animation system then let each particle know about its neighbors- so each key wanted to follow the leader and be close to its neighbor, but not too close. Computer scientist Craig Reynolds first published a paper on behavioral animation at Siggraph in 1987, so this technology is rather taken for granted these days, but it's still a lot of work." Also in the sequence are five CG Harry shots, realized by Imageworks. Harry brings the scene to a close by grabbing the gimpy key, tossing it to Hermione, then zipping after his friends through the unlocked door, which Hermione slams, causing pursuing keys to spill across its surface.

Harry, Hermione and Ron enter the next chamber and find a huge playing field of sixty-four black and white squares, with two armies of ten-foot-tall chessmen waiting to do battle, ominously echoing the earlier wizard chess game. Stuart Craig and Rob Legato elected to shoot the scene in a full-scale set, using full-scale pieces augmented by physical effects and selective CG character animation. "Once Stuart's team had built the six



In the final chamber, Harry discovers Professor Quirrell (Ian Hart) puzzling before the Mirror of Erised, which reveals, inexplicably and to Harry

main pieces,” noted Legato, “it just became a matter of casting the full set from those molds and applying different paint jobs; so it made sense to build the whole thing practically. Stuart designed a pit around the board, filled with broken pieces to suggest that this game has been going on for ages. When John Seale lit it all with flaming torches, it looked pretty great.”

alone, that the Sorcerer's Stone is now in the hands of the young wizard's grasp. As he did this, he was also displaying the stone publicly with the dark wizard, whose physiognomy protrudes hideously from the back of the professor's head. Artists at ILM created a CG Voldemort face for the scene and tracked the imagery to the back of Hart's bald pate. Realistic skin shaders and a revised facial animation system allowed for convincing facial expression and lip sync.

Nick Davis and Karl Mooney supervised visual effects plate photography for the giant chess game. John Richardson's team created pyrotechnics for the chess piece impacts, rigging fiberglass props with breakaway plaster sections that were triggered by compressed air rams and wire pulls. Mill Film provided animation for the queen and pawns. “CFC's Soho cyberscan facility scanned the four-inch chess pieces,” recalled Mill Film senior CG artist Royston Willcocks. “We loaded these into Cyslice and created a network of NURBS patches that we could use in Maya. Laurent Kermel oversaw texturing using stills of the large-size pieces on set, then Wayde Duncan-Smith and Val Wardlaw set up characters for Andrew Brownlow, who animated the pawn, and Rudy Raijmakers, who animated the queen.” Following Chris Columbus' brief to produce single-minded sculpted assassins, Brownlow and Raijmakers animated the digital characters to shake and stagger as they delivered blows that interacted with live pyrotechnics. Character setups by Duncan-Smith and Wardlaw enabled shoulder armor to rotate and react to collisions, while CG supervisor David Lomax provided peripheral fluidity in the queen's skirt and in the pawn's carapace. A ten-person compositing team then blended lighting passes and layered digital characters into the scene with a speedy, interactive batch process—using Flame to instantly assemble textures and color passes in the manner of a 3D shader—developed by Mark Hopkins and Bruno Lesieur.

Ron's mastery of chess saves the day in the chess chamber, then Harry enters the last room alone. Inside, he finds a circular chamber ringed by eight-foot-tall tongues of flame— a practical effect fueled by propane— where Professor Quirrell (Ian Hart) waits for him, beside the Mirror of Erised. Quirrell then reveals the extent of his collaboration with Lord Voldemort by unraveling a turban, unveiling Voldemort's hideous visage, protruding from the back of Quirrell's bald head. “The way we interpreted it from the book,” said Rob Legato, “Voldemort was a parasitic entity searching for a form that he couldn't quite fill, so he was constantly trying to solidify; then as he failed, he would sink back into Quirrell's head. This gave us the idea that whenever Voldemort extended from the back of Ian's head, we would see Quirrell's skin stretch taut; and as Voldemort spoke, it would cause Quirrell's jaw to move. We started to plan this as a half-prosthetic, half-CG effect. Nick Dudman created an appliance for Ian Hart to wear that caused his skin to stretch as ILM extruded Voldemort from the back of his head. Towards the end of the schedule, Chris Columbus became a bit concerned about how much time the prosthetic might take to shoot, so we came up with an alternative approach.”

The first priority on set was to insure a means by which an entirely digital Voldemort face could be affixed to the live Quirrell's head. “Nick Dudman helped me figure out a technique,” said Roger Guyett. “We took a lifecast of Ian Hart's head, made a vacuform template from that, then

drilled a series of holes into the template, held it up to the actor and painted through the holes to mark his head. This gave us a consistent series of tracking markers on the back of Quirrell's head from one day to the next. It was complicated because we weren't working with a rigid shape, but with the moving skin of a human head. Our match-move crew took Nick's plaster cast of Ian, scanned that and worked out the underlying skull shape to help us track our CG head to the back of the actor's head. This gave us a firm foundation to allow Chris Columbus to do whatever he wanted with Ian on the set." Columbus covered Hart's performance with a dynamic, roving camera- sometimes staging shots that featured Voldemort and Harry, with Quirrell's head reflected in the Mirror of Erised. "The reflections in the mirror raised all sorts of issues that Hilmar Koch, the sequence supervisor, had to figure out. It effectively doubled our work, since you could see Voldemort not only in the foreground, but also in the mirror. Hilmar took the match-move from the master scene, and reversed it, then used that information to drive the performance in the mirror. We had to add an antique patina to the surface of the plain glass we had shot for the mirror. Under normal circumstances, that might have been straightforward; but the whole scene was lit by flickering firelight, so light levels were constantly changing, on the mirror as well as on people's skin."

Paul Giacoppo modeled Voldemort's physiognomy, and Susan Ross supervised the painting of skin textures, based on a skin shader Koch developed for the show. The shader re-created real skin subsurface light scattering, and included veins and skin imperfections. "The book, when it describes Voldemort's emergence, leaves a lot to the imagination," commented Guyett. "We started with Voldemort looking pretty snakelike, very pale with red eyes, as the book suggests; but we made him slightly more human as we went along. The biggest undertaking was trying to achieve Voldemort's constantly shifting character. Cary Phillips redesigned our in-house facial animation system, Caricature, and created a very flexible tool that allowed us to design a basic model of facial expressions and then make the underlying creature morph through different stages. We called each of the stages 'states' and, with our revamped Cari software, we could animate through a series of Evolutionary changes while maintaining a consistent performance."



Physical contact with Harry proves lethal for Quirrell, whose hand and arm begin to crumble in a reaction that spreads quickly to the rest of his body, turning the wizard to ash. ILM generated the disintegration effect with shaders and particle systems applied to a CG likeness of Ian Hart and used in conjunction with a collapsing Quirrell gag engineered on set by the physical effects team.

Ian Hart provided the voice of Voldemort, timing his performance as Quirrell to become more passive as Voldemort grew more powerful. David Andrews directed a team of three animators- Lou Dellarosa, Scott Benza and Steve Alpin- to orchestrate Voldemort's performance in his primary facial state. "Ian Hart's reading as Voldemort was very energetic," said Andrews. "He sounded a bit like Richard Harris- wizened, but very enunciated with super gyrating mouth-shapes. I knew Chris wanted realism, so we toned down the animation by half; but when we showed it to Chris, he still thought it looked like Hammer horror! So we brought it down another notch, anticipating sounds with mouth shapes to keep the delivery percussive without its getting mushy." Scott Benza then linked Voldemort's primary performance to Paul Giacoppo's range of facial states, timing different quadrants to rise and fall from the back of Quirrell's head, sometimes almost imperceptibly. "We did not want 'cartoony' grotesque- we just wanted grotesque."

As Harry gains possession of the Sorcerer's Stone, Voldemort seizes him by the wrist. Physical contact with the young wizard has an immediate effect on Voldemort. ILM generated an effect that turned the character to ash, first crumbling away Quirrell's hand, spreading up his shoulder to his head, then disintegrating his entire body before Harry's eyes. Digital artist Doug Sutton came up with the skin ash transition using RenderMan shaders and particle systems. John Richardson's physical effects team, in collaboration with the wardrobe department, applied finishing touches to the effect, supplying Quirrell clothing built over a collapsible structure that could crumble on cue and create clouds of dust. ILM CG supervisor Gerald Gutschmidt, Hilmar Koch and a team of digital artists then animated the collapse through detailed match-move, tracking and particle rendering. "We developed a digital version of Ian Hart that allowed us to go through the full sequence of his disintegration," said Roger Guyett. "A lot of paint work was needed to remove Ian from the original plates, but we were lucky to have digital painter Beth D'Amato on the show."

Just when Voldemort seems finally finished, he returns as a spirit that rises from the ashes. Khatsho Orfali and Raöl Essig developed the look of the spirit as a swirling, smoky presence- a digitally rendered particle animation- that swoops up and momentarily skewers Harry. "The scene was somewhat different from the book," observed Guyett, "but Chris always conferred with J.K. Rowling on all of his ideas. He wanted this effect to differ from the classic 'spirity' effects we've seen in Raiders of the Lost Ark. It was much less physical and not self-illuminating, and it was purposely designed to leave the audience with some ambiguity as to whether or not Voldemort had survived to come back another day."

At an end-of-year banquet held in the Great Hall, Dumbledore rewards Harry and his friends house points for their bravery in dispatching Voldemort, resulting in Gryffindor's defeating



The spirit of Voldemort rises from the ashes and passes through Harry before vanishing up a shaft. ILM employed particle animation to produce the smoky, swirling presence, deliberately designing the effect to suggest some ambiguity as to whether Voldemort has, in some form or another, survived his encounter with Harry.

presumed winner Slytherin in the annual inter-house competition. Giant banners hanging high above the hall, bearing the black-and-silver Slytherin snake, transform to the Gryffindor gold-and-scarlet lion- a digital animation supplied by Mill Film, the last of 700 visual effects shots in the film- signaling a triumphant end to Harry Potter's first year at Hogwarts.

For the international army of artists and technicians associated with Harry Potter and the Sorcerer's Stone, the production was unique not only in the volume of visual effects it employed in the service of its story, but also for its diversity of techniques- practical and digital. "It was amazing to realize that all of the work we put into the centaur, for example, was seen in just five shots," Jim Berney noted, "or all the work that went into Fluffy, who's only in seventeen. We've had projects where we put that much work into a character used for 500 shots!"

For the legion of fans who would scrutinize every step of the production, one of the most encouraging signs during filming was the voice of J.K. Rowling, who acted as advisor and collaborator from the project's early days. "There was never anything that she disapproved of," remarked Rob Legato. "There were a few scenes- Platform 9 3/4, the Mirror of Erised, and Quidditch in particular- where she was very supportive. She was fascinated by Stuart's designs for the Quidditch stadium and what we did with The Game, because that was always such a big part of her books. What I found interesting about the books was that they were reminiscent of archetypes we've all either read or heard about before. The stories were almost like a collection of fables and mythology blended into this one magical setting. That was why we tried to keep the film in a familiar zone, without making anything too outlandish. The images in the picture might remind you of themes or characters you've come across before, but you can't quite put your finger on them. Interpreting that fine line was the magic trick."

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